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BLACK FLIES (DIPTERA, SIMULIIDAE) OF THE SWAN HILLS, ALBERTA AS POSSIBLE VECTORS OF *ONCHOCERCA CERVIPEDIS* WEHR AND DIKMANS, 1935 (NEMATODA, ONCHOCERCIDAE) IN MOOSE (*ALCES ALCES* LINNAEUS)

by

© DAVID JAMES PLEDGER

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF ENTOMOLOGY

EDMONTON, ALBERTA
FALL, 1978

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Black Flies (Diptera, Simuliidae) of the Swan Hills, Alberta as Possible Vectors of Onchocerca cervipedis Wehr and Dikmans, 1935 (Nematoda, Onchocercidae) in Moose (Alces alces Linnaeus)" submitted by David James Pledger in partial fulfilment of the requirements for the degree of Master of Science in Entomology.

D A Craig
Supervisor

William M. Samuel

R. H. Gooding

Date 15 Oct 1978

To the memory of

Leslie Pledger

and

Calvin Bohmer

ABSTRACT

The filarioid nematode of moose (*Alces alces* Linnaeus) known as "legworm" and their possible vector, the adult black fly (Simuliidae), were studied in the Swan Hills, Alberta from 1975 to 1977. Legworms recovered from the subcutaneous connective tissue of hunter-killed and live-trapped moose were identified as *Onchocerca cervipedis* Wehr and Dikmans, 1935. Sixty-four percent of the moose examined were infected with adult legworms of which 80.0% were located in the forelimbs and 20.0% in the hind limbs. There was a linear increase in number of adult legworms with increasing age of moose. Immature moose (<1.5 years) were not infected. *Onchocerca cervipedis* microfilariae were present in the skin of the fore and hind limbs of live trapped and hunter-killed moose during June and July only.

The adult populations of twenty-one black fly species were monitored from muskeg and deciduous-coniferous forest communities in 1976 using modified malaise traps, carbon dioxide-baited barrel traps and insect sweep nets. Adults of *Simulium venustum* were most abundant; followed by *S. decorum*, *S. pugetense*, *S. arcticum*, *S. latipes*, *S. meridionale*, *S. euryadminiculum* and *S. furculatum*.

New Alberta records are reported for *Simulium jenningsi* and *S. euryadminiculum*.

Adults of 14 black fly species were collected from live trapped moose and a penned moose. Individuals of *S. decorum*, *S. venustum*, *S. vittatum*, *S. arcticum*, *S. aureum* and *Prosimulium formosum* took

blood meals. Onchocerca cervipedis microfilariae were found in the blood meals of only S. decorum and S. venustum incriminating these species as possible vectors of moose legworm.

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I. INTRODUCTION

The filarioid nematode *Onchocerca cervipedis* Wehr and Dikmans, 1935 (Nematoda, Onchocercidae) a parasite of North America cervids, was investigated in moose (*Alces alces* Linnaeus) from the Swan Hills, Alberta during 1975-1977. Concern expressed by Alberta Government wildlife biologists, that hematophagous flies (Diptera) would be a major consideration in successfully developing wild ungulate farming in subagricultural areas of Alberta, stimulated this research. No information was available on biting flies attracted to or blood feeding on wild ungulates in Alberta and little was known about the biting flies inhabiting non-agricultural areas. *Onchocerca cervipedis* which is widely distributed in moose throughout their western and northern ranges in Alberta has received little attention aside from occurrence records and a study by Samuel *et al.* (1976). In California the black fly (Simuliidae) *Prosimulium impostor* Peterson has been incriminated in vectoring *O. cervipedis* in Columbian black-tailed deer, *Odocoileus hemionus columbianus* (Richardson) (Weinmann *et al.*, 1973). The possibility of biting flies vectoring *O. cervipedis* in moose provided an opportunity to study both parasite and biting flies affecting moose in Alberta.

Basic criteria for incriminating an arthropod in transmission of causal agents of disease are: 1) demonstration of effective contact with the host under natural conditions; 2) a temporal and spatial association of suspected arthropod species and occurrence of infection in host; 3) repeated demonstration that the arthropod harbours the infectious agent in the infective stage under natural conditions and 4) demonstrate transmission of agent under controlled conditions (Barnett, 1960 in James and Harwood, 1971).

The objective of this study was to provide a more comprehensive understanding of host-vector-parasite relationship of the legworm, O. cervipedis, in moose of central Alberta by following the above criteria. Specific goals were to: 1) confirm the identification of O. cervipedis, (Samuel et al., 1976) in Alberta moose; 2) determine the prevalence (proportion of the population infected) of legworm in relation to host age and sex; 3) determine temporal and spatial distribution of microfilariae in moose; 4) determine seasonal occurrence of adult black flies in the Swan Hills, north central Alberta; 5) determine the identity of adult black flies blood feeding on moose in the Swan Hills and 6) identify possible black flies vector(s) of O. cervipedis.

Many species of hematophagous flies were collected from moose at the study site in the Swan Hills, but since Weinmann et al. (1973) incriminated only P. impostor in vectoring O. cervipedis in Columbian black-tailed deer, only black flies were considered in this study.

II. LITERATURE REVIEW

A. Taxonomy of Legworm

The first North American report of legworm in cervids was by Hassall in 1893 who identified *Onchocerca flexuosa* (Wedl, 1856), a parasite of European cervids, from a deer (probably a Columbian black-tailed deer, *Odocoileus hemionus columbianus*) in a zoo (Dikmans, 1933). Wehr and Dikmans (1935) described *O. cervipedis* based on specimens in white-tailed deer, *Odocoileus virginianus* (Zimmermann), from Montana and Gambier Island, British Columbia. They distinguished it from *O. flexuosa* mainly on the basis of spicule measurements, absence of caudal alae and on number of papillae in the male. Later, Caballero (1945) proposed the new generic name *Wehrdikmansia* for the species, primarily on the basis of absence of annular thickenings on the cuticle. Recently, Bain and Schulz-Key (1974) showed a continuum from smooth cuticle to annular ridges among species in *Onchocerca*, and relegated *Wehrdikmansia* to a synonym of *Onchocerca* Diesing, 1841.

B. Legworm Hosts and Geographic Distribution

The restricted geographic distribution intimated in early work with legworm (Rush, 1935) and the limited number of definitive hosts (Herman, 1945) has not been upheld. Legworm now has been reported in white-tailed deer from Arizona (Hibler, 1965), Idaho (DeNio and West, 1942), Montana (Rush, 1935), Pennsylvania (Beaudoin *et al*., 1970) and British Columbia (Wehr and Dikmans, 1935); in Rocky Mountain mule deer

(Odocoileus hemionus hemionus (Rafinesque) from Arizona (Hibler, 1965), California (Annereaux, 1941; Herman and Bischoff, 1946), Idaho (DeNio and West, 1942), Utah (Yuill et al., 1961) and British Columbia (Cowan, 1946) in California mule deer (Odocoileus hemionus californicus Caton) from California (Herman and Bischoff, 1946); in Columbian black-tailed deer from California (Herman and Bischoff, 1946; Weinmann et al., 1973), Washington (Yuill et al., 1961; Brown, 1961) and British Columbia (Wehr and Dikmans, 1935; Cowan, 1946); in pronghorn antelope (Antilocapra americana (Ord.)) from Idaho (Dikmans, 1933); and in wapiti (Cervus elaphus (Linnaeus)) in Idaho (deNio and West, 1942).

The first record of legworm in moose (Alces alces) was from Ootsa Lake, British Columbia (Hatter, 1946 in Cowan, 1951). Since then legworm in moose has been reported from Wells Grey Provincial Park, British Columbia (Ritcey and Edwards, 1958), Alaska (Williams, 1958), Ontario (Anderson, 1962) and Alberta (Samuel et al., 1976).

C. Legworm Pathogenicity

DeNio and West (1942) suggested that the initial stimulus for research on O. cervipedis seemed to have been the possible damaging effects of the parasite on cervids. Rush (1935) following reports by Montana hunters that local white-tailed deer had foot rot Spherophorus necrophorus Prevot, found legworms only during examination of two deer. Those infected with legworm had loose or missing 2nd and 5th digits with swelling and ulcers in the toe area. Annereaux (1941) and Herman (1945) felt that legworm infections could cause lameness and mortality in deer. Herman and Bischoff (1946) and Herman (1947) attributed open skin lesions in the lower limbs of deer to this parasite, but saw no visible evidence of any other harmful effects. More recent literature (Cowan, 1951; Ritcey and Edwards, 1958; Yuill et al., 1961; Anderson, 1962 and Weinmann et al., 1973) have not found symptoms such as reported in earlier literature. Weinmann et al. (1973) suggested that nodular development and associated lesions may be indicative of a less than optimal host-parasite relationship. The actual or potential harm of O. cervipedis for their host is uncertain and has remained unstudied.

The pathology of filarial infections was reviewed by Nelson (1966). Damage is usually caused by chronic inflammatory reactions around dead and dying worms, but may be influenced by the number of worms harboured by the host, parasite longevity, immune response of the host, the strain of the parasite and the strain and sex of the host. Wild and domestic animals rarely show severe complications in filariasis, perhaps due to shorter life-expectancy of the host (Nelson, 1966), whereas in Kenya, 11 years after the eradication of the vector of Onchocerca volvulus (Leuckart 1893) in 1946, more than 50.0% of the human populus in the "Valley of the Blind" had microfilariae in their blood and many had progressive onchocercal dermatitis and eye disease (Nelson and Grounds, 1956 in Nelson 1966). However, Nelson (1966) reported on experimental studies by MacDonald and Scott (1953, 1958); Bertram (1953, 1958, 1959); Scott et al. (1958) and Ramakrishnan et al. (1961) on Litomosoides carinii (Travassos, 1919) and by Duke (1960a) on Loa loa Cobbold in monkeys which indicate that animals can develop an immunity to these parasites. An immune response may result in a reduction in the worm burden, as shown in dogs infected with Dirofilaria immitis (Leidy, 1856) (Wong, 1964; Hawking, 1965 in Nelson 1966).

Different strains of O. volvulus in Africa and Central America may account for clinical differences observed but differences in pathogenicity are usually thought due to differences in biting habits of the vectors (Brumpt, 1936 in Nelson 1966). In Samoa, Wuchereria brancrofti (Cobbold) was more pathogenic in Caucasians than in non-caucasians (Webster, 1946 in Nelson 1966) an indication that different strains of host could influence pathogenicity of filarial infections. Higher densities of O. volvulus have been observed in human males than females indicating a host-sex preference (Nelson, 1958b).

D. Adult Legworm Distribution in Host

Adult legworms preferentially inhabit subcutaneous connective tissue of lower limbs around the tibio-tarsal joints (Rush, 1935; Herman, 1945; Annereaux, 1941; Herman and Bischoff, 1946; Cowan, 1951; Ritcey and Edwards, 1958; Anderson, 1962; Anderson and Lankester, 1974; Samuel et al., 1976), although they have been reported elsewhere in the host body particularly when legworms are numerous. In Columbian black-tailed deer, legworms were found in the intermuscular and subcutaneous tissues in the sides and back (Cowan, 1946), and in the back of the neck and the base of the ears (Herman, 1947). In moose (Ritcey and Edwards, 1958) and mule deer (Yuill et al., 1961), legworms were observed subcutaneously in the brisket and limbs. Hibler (1965) recovered 15 female and seven male worms from the base of the conchal cartilage of a white-tailed deer ear. Since male worms were abundant at the base of ears and rare elsewhere in the host, he felt this was preferred legworm location. Weinmann et al. (1973) found legworms most commonly in the limbs, but also in the shoulder, flank, belly and brisket of Columbian black-tailed deer.

Depending on host and geographic location, adult legworms seem to exhibit a preference for either the fore or hind limbs. Preference for the hind limbs has been reported in Columbian black-tailed deer from British Columbia (Cowan, 1951) and California (Weinmann et al., 1973), and in moose from Algonquin Provincial Park, Ontario (Anderson, 1962). Samuel et al. (1976) found that 83.0% of the legworm in 33 infected moose from Alberta were in the fore limbs. Brown (1961) also found legworms more abundant in fore limbs than hind limbs of Columbian black-tailed deer from Washington, but Herman and Bischoff (1946) found no preference of legworm for either hind or fore limbs in Columbian black-tailed deer and mule deer from California.

E. Adult Legworm Condition in Host

In the subcutaneous connective tissue of their host, adult legworms are found in extended and coiled positions, with coiled worms sometimes encysted in fibrous tissue to form a nodule (Rush, 1935; Herman and Bischoff, 1946; Cowan, 1951). Wehr and Dikmans (1935) and Rush (1935) indicated that mature legworms coil and stimulate the formation of fibrous cysts after mating. This agrees closely with the findings by Schulz-Key (1975a) on O. flexuosa development in red deer (Cervus elaphus) from Germany where immature female legworms induced development of the nodule in red deer fawns (4-6 months old). Male legworms entered the nodule, which contained 1 to 4 females, and mated with the female legworms. As development of eggs occurred the female thickened and curled, leaving only the anterior extremity protruding from the nodule to release microfilariae (Schulz-Key, 1975a).

F. Prevalence of Adult Legworm

While no host-sex preference has been demonstrated by O. cervipedis (Yuill et al., 1961; Weinmann et al., 1973), there is a relationship between the number of legworms and the age of the host. Deer fawns and moose calves were not commonly infected (Herman and Bischoff, 1946; Ritcey and Edwards, 1958; Yuill et al., 1961; Beaudoin et al., 1970; Weinmann et al., 1973; Samuel et al., 1976).

Beaudoin et al. (1970) reported a prevalence of 5.6% of O. cervipedis in white-tailed deer fawns from Pennsylvania, 28.0% in deer 1 to 3 years of age and 62.5% in deer over 3 years of age. Weinmann et al. (1973) noted a similar increase in the prevalence of legworm in Columbian black-tailed deer of California (fawns 7.1%, deer 1-3 years 62.9%, 3+ years old 86.5%) as did Samuel et al. (1976) for moose(calves 11.0%, moose over 16 months of age, 73.0%). This increase was not linear (Weinmann et al., 1973) and may be influenced by age composition and density of the definitive host (Beaudoin et al., 1970).

G. Adult Legworm Sex Ratio

Male legworms are rarely encountered. A sex ratio of 1.7:100 male:female has been reported in Columbian black-tailed deer, California and Rocky Mountain mule deer, by Herman and Bischoff (1946) and a 3.3:100 ratio in Columbian black-tailed deer by Weinmann et al. (1973). Herman and Bischoff (1946) suggested that males inhabited areas in the host above the tibio-tarsal joints that were not examined.

H. Legworm Microfilariae Distribution in Host

Rush (1935) suggested that lesions created in the skin of the host by the female legworms were a means of releasing the eggs or microfilariae, and that they were probably transmitted to the aquatic immature stages of "flies or mosquitoes". Herman and Bischoff (1946) examined blood, lymph and skin scrapings of Columbian black-tailed deer and California and Rocky Mountain mule deer in search of microfilariae with no positive results. Little more was learned about the microfilariae until Anderson (1962) suggested that since "*Wehrdikmansia* has close affinity to *Onchocerca*", microfilariae were in the host skin, and were likely to be transmitted by black flies or ceratopogonid adults. He felt that soaking skin tissue samples in saline solution would reveal microfilariae. Hibler (1965) examined blood, skin, heart and lung tissues of Arizona white-tailed deer and mule deer in search of microfilariae, but recovered them only from skin samples in close association with the adult legworm in the ears.

Weinmann (1973) found microfilariae of *O. cervipedis* only in ear of Columbian black-tailed deer even though adults were only in the legs. This appears to be an adaptation for encountering vectors which prefer to feed on certain areas of the host (Weinmann *et al.*, 1973). The localization of microfilariae in the skin of the host in a place distant from the adult legworm has been reported in other members of *Onchocerca*. Schulz-Key (1975) reported a complex of subcutaneous filarioids in red deer from Germany. Adults of *O. flexuosa* inhabited the back and flanks of the host while microfilariae localized in the skin of the inner aspect of the hind limbs; *Onchocerca tarsicola* Bain and Schulz-Key, 1974, were located on the abductor tendons of the tibio-tarsal or radio-carpal joints while the microfilariae localized in the skin of the outer parts of the ear and nose; and Onchocerca tubingensis Bain and Schulz-Key, 1974 were found in the caudal part of the back with the microfilariae concentrating around the sternum and the inner aspect of hind legs. Adult Onchocerca gutturosa (Newman, 1910) live in the cervical ligaments of cattle from England, while the microfilariae concentrate in the skin of the umbilicus region (Eichler and Nelson, 1971; Eichler, 1971). The umbilicus region is the preferred blood feeding site of the vector, Simulium ornatum (Meigen, 1818) (Eichler, 1971).

I. Periodicity of Microfilariae in Host

Weinmann (1973) reported seasonal periodicity of O. cervipedis microfilariae in Columbian black-tailed deer from California. Monthly skin biopsies taken from the ear of deer showed microfilariae were abundant during the spring and summer. An examination of female O. cervipedis revealed a high proportion were gravid between late January and April, but sparse in July and absent during the fall and early winter. Seasonal periodicity of O. gutturosa microfilariae in cattle from England has been shown by Eichler (1971, 1973) with numbers of microfilariae increasing from May to August and coinciding with seasonal activity of the vector, adult S. ornatum. Sasaki et al. (1954 in Nelson, 1970) has also demonstrated seasonal periodicity of Onchocerca cervicalis Railliet and Henry, microfilariae in the skin of horses. Diel periodicity of O. volvulus microfilariae in the skin of humans has been demonstrated by Lartigue (1967 in Nelson, 1970) in West Africa, by Wegesa (1966a in Nelson, 1970) in East Africa and in

The "Camerons" by Duke et al. (1967 in Nelson, 1970).

J. Microfilariae in Vector

Members of the genus Onchocerca require ingestion by a suitable vector species before development proceeds beyond the microfilarial stage. Weinmann (1973) has incriminated the female black fly, Prosimulium impostor Peterson, in vectoring O. cervipedis to Columbian black-tailed deer in California, but nothing is known about this parasite in the vector. However, the microfilariae of O. volvulus (Lewis, 1950; 1953b in Nelson, 1970) and O. gutturosa (Eichler, 1973) following ingestion by their vector, penetrate the gut and migrate through the hemocoel to the flight muscles where development continues. The average migration time of O. gutturosa microfilariae to the flight muscles of S. ornatum was six hours, with 25.0% of the microfilariae moving from the gut within one hour (Eichler, 1973). Two molts occur before Onchocerca larvae reach the infective stage. In O. volvulus the infective stage is reached 6 to 7 days following ingestion of the microfilariae and this is temperature dependent (Nelson and Pester, 1962; Wegesa, 1966b in Nelson, 1970).

The number of microfilariae ingested by the vector varies with the vector species (Strong et al., 1934 in Nelson, 1970) and is dependent on the time the vector spends feeding (Wegesa, 1966b in Nelson, 1970). Not all microfilariae ingested are successful in developing to the infective stage as mechanisms in the vector regulate the number of microfilariae. In Simulium damnosum Theobald, 1903 less than 50.0% of the O. volvulus microfilariae ingested develop to the infective stage (Lewis and Duke, 1964 in Nelson, 1970). Omar and Garns (1975) showed the buccopharyngeal armature to be an important mechanism in regulating numbers of _O. volvulus_ microfilariae reaching the gut in _Simulium ochraceum_ Walker. The cibarial teeth damage the microfilariae enroute to the gut. The peritrophic membrane is another regulating mechanism and early penetration of the gut wall by the microfilariae before the membrane thickens and hardens is thought to be important for survival of _O. volvulus_ in _S. damnosum_ (Lawrence, 1966 in Nelson, 1970) and _O. gutturosa_ in _S. ornatum_ (Eichler, 1973). However, in seven nearctic adult black fly species studied by Yang and Davies (1977) the peritrophic membrane formed in 30 minutes but required several hours (6 to 12 hours) to harden. Slower hardening of the peritrophic membrane around the anterior of the blood bolus may provide an opportunity for parasites in the blood meal to escape the peritrophic membrane (Yang and Davies, 1977). Coagulation of the blood meal and age of microfilariae may also be involved in regulating the numbers of microfilariae successfully penetrating the gut (Erichler, 1973).

K. Black Flies as Vectors

Knowledge of the role of insects in the transmission of pathogens to man and other animals had its beginning in 1878 when Manson discovered _W. bancrofti_ larvae in a mosquito. Members of the Family Simuliidae are instrumental in transmission of pathogens of medical and veterinary importance to man, his domestic animals and wild animals. Reviews by Griener _et al_. (1975) and Fredeen (1977) summarize pathogens transmitted by black flies in North America. Fallis (1964 in Fredeen, 1977) and Anderson _et al_. (1961 in Fredeen, 1977) reported Eastern Equine Encephalitis virus in _Simulium johannseni_

Hart, 1912 and *Simulium venustum* Say, while the virus causing myxomatosis in rabbits has been experimentally transmitted by black flies (Fredeen, 1977). As vectors of avian hematozoa, simuliids transmit trypanosomes (Bennett, 1961 in Griener *et al*., 1975) and leucocytozoons (Bennett and Fallis, 1966 in Griener *et al*., 1975; Skidmore, 1932 in James and Harwood, 1971).

The black fly vector species of *O. volvulus* may vary from one geographic area to another. In Africa the main vectors are adults of *S. damnosum*, however, in East Africa the primary vector is *Simulium neavei* Roubaud (Raybould, 1967 in Nelson, 1970). Adults of *Simulium callidum* Dyar and Shannon, *Simulium metallium* Bellardi and *S. ochraceum* have been incriminated as vectors of *O. volvulus* in Central and South America (Dalmat, 1955 in Nelson, 1970). *Simulium orchraceum* is the primary vector in Guatemala (Deleon and Duke, 1966), while *S. metallicum* is probably the main vector in Venezuela (Arends, 1966 and others in Nelson, 1970). A given vector species may have sibling species with slightly different characteristics which could influence their potential as effective vectors (Lewis 1960a, 1965; MaCrae, 1968 and others in Nelson, 1970).

L. Black Fly Research in Alberta

Black fly research in Alberta, aside from major taxonomic works, has been restricted primarily to species occurrence (Strickland, 1938; 1946) with emphasis on agricultural and south Rocky Mountain forest areas (Fredeen, 1958; 1969; Fredeen and Shemanchuk, 1960; Abdelnur, 1968; Depner, 1971; Peterson and Depner, 1972). Barr (1977) included 44 species of black flies in a list of Nematocera of Alberta based on a literature review.

M. Black Flies Affecting Moose

Records of black fly adults that feed on the blood of moose are rare even though these cervids are bothered by biting flies (Murie, 1934; Peterson, 1955; Flook, 1959). No records of black fly adults blood feeding on moose have been reported in Alberta; however, *S. venustum* and *Simulium pictipes* Hagen were collected from moose in Minnesota (Olsen and Fenstermacher, 1942; Nickolson and Mickel, 1950) and Flook (1959) in Northwest Territories collected *Simulium luggeri* Nickolson and Mickel and *Simulium malyschevi* Dorogostajskij, Rubzov and Wasenko from an area a moose had just left.

III. STUDY SITE

The study site is located in a 600 square kilometre study area of the Alberta Fish and Wildlife Division in the eastern fringe of the Swan Hills (Figure 1). The area is 157 kilometres northwest of Edmonton, Alberta, Canada (54° 46' N 115° 5' W) and is part of the Athabasca River Drainage Basin.

The climate is continental and characterized by cold winters and short, cool summers. The average January temperature is -15.0°C and the average July temperature is 15.6°C (Langley, 1967). The western Swan Hills receives about 15-20 centimetres of precipitation more than adjacent areas per annum, with an average May-September precipitation of about 51 centimetres (Anonymous, 1976). Weather records were maintained at the study site for the 1976-1977 field seasons (Appendices 1 and 2).

The Swan Hills are underlain by sandstone, shales and coals of Cretaceous age; and by hardened clays, sandstone, shales and quartzite gravels from the Tertiary period. The grey wooded soils overlying the parent material are susceptible to leaching, resulting in deficiencies in nitrogen, phosphorus and organic material (Green and Laycock, 1967). The well drained upland soils are primarily orthic grey luvisols, while the poorly drained lowland soils are gleysols (Anonymous, 1976).

The study site was in the lower Foothills Section of the Swan Hills which is a transition zone between the Transcontinental Boreal Forest and the Rocky Mountain Subalpine Forest (Cordilleran). The

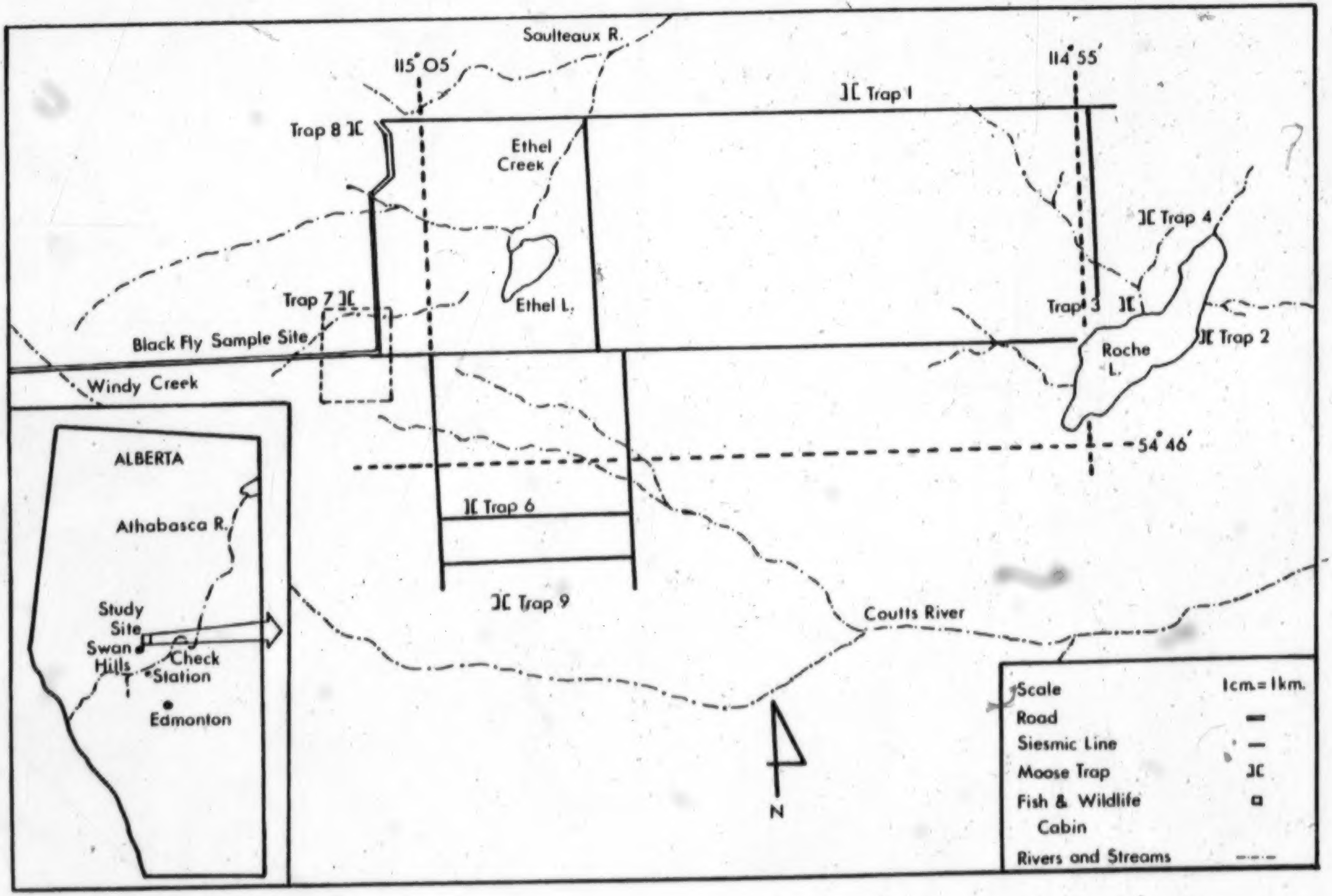
Saulteaux R.
115° 05′
114° 55′
Trap 1
Trap 8
Ethel Creek
Trap 4
Ethel L.
Trap 7
Trap 3
Trap 2
Black Fly Sample Site
Roche L.
Windy Creek
54° 46′
ALBERTA
Trap 6
Athabasca R.
Trap 9
Study Site
Coutts River
Swan Hills
Check Station
Edmonton
N
Scale 1cm.= 1km.
Road
Siesmic Line
Moose Trap
Fish & Wildlife Cabin
Rivers and Streams

Figure 1. Location of Swan Hills Study Area.

flora shows characteristic species from both biomes with species such as lodgepole pine (*Pinus contorta* Douglas), Englemann spruce (*Picea engelmanni* Parry), and subalpine fir (*Abies lasiocarpa* (Hooker) Nuttal) of the Cordilleran region and white spruce (*Picea glauca* (Moench) Voss), balsam fir (*Abies balsamea* (L.) Miller), black spruce (*Picea mariana* (Miller) Britton, Sterns, Poggenburg) and jack pine (*Pinus banksiana* Lambert) of the Boreal Forest (Anonymous, 1976). The moose population in the Alberta Fish and Wildlife Division study area, based on an aerial census in December, 1977, was 1.8 moose per square kilometre (Lajeunese pers. commun., 1978). Wild moose were live trapped by the Alberta Fish and Wildlife biologists between the corner cabin (54° 46' N 115° 5') and Roche Lake (54° 45' N 114° 55'). Nine moose traps were located along game trails to mineral licks (Figure 1). A penned moose was maintained at the corner cabin site (Figure 2). Several small streams in the study area provided suitable aquatic habitats for the immature black flies (Figure 1). Ethel Creek, Windy Creek and an unnamed stream flowing out of Roche Lake had lake origins and were permanent in nature, while two unnamed creeks, the Coutts River and the Saulteaux River had muskeg origins. The Athabasca River is the major lotic system in the immediate area being about 29 kilometres east of Roche Lake.

Black fly species were monitored from a muskeg (Figure 3) and mixed deciduous-coniferous forest community (Figure 4) adjacent to the corner cabin. The trapping sites are shown on Figure 2.

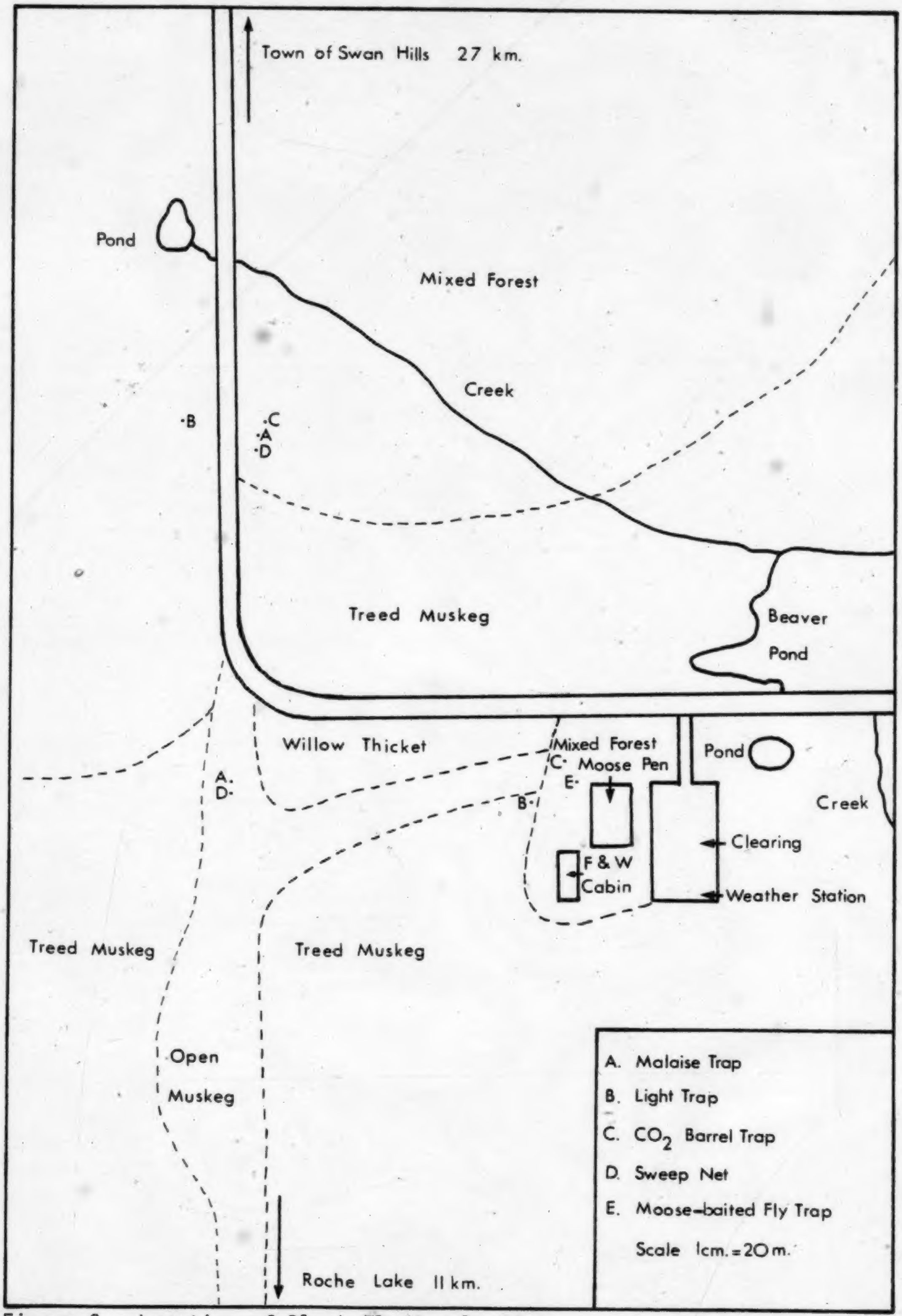
Town of Swan Hills 27 km.
Pond
Mixed Forest
Creek
·B
·C
·A
·D
Treed Muskeg
Beaver Pond
Willow Thicket
Mixed Forest
C· Moose Pen
E·
B·
Pond
A·
D·
Creek
Clearing
F & W Cabin
Weather Station
Treed Muskeg
Treed Muskeg
Open Muskeg
Roche Lake 11 km.
A. Malaise Trap
B. Light Trap
C. CO2 Barrel Trap
D. Sweep Net
E. Moose-baited Fly Trap
Scale 1cm.=20m.

Figure 2. Location of Black Fly Sample Sites.

Figure 3. Muskeg Community Black Fly Sampling Area in Swan Hills.

Figure 4. Forest Community Black Fly Sampling Area in Swan Hills.

3

4

IV. TAXONOMY OF PARASITE

A. Materials and Methods

Onchocerca cervipedis specimens collected from nine wild moose and preserved in 70% ethanol were used for identification. Seven males, 10 females and 16 microfilariae were cleared by gradually adding glycerol to the sample and permitting the alcohol to evaporate over a five to seven day period. Specimens were then mounted in beechwood creosote and lactophenol (1:1) and examined at 128 power with a binocular compound microscope (Carl Zeiss, Ortholux). Measurements of all characters were made with a calibrated ocular graticule, except for the total length of female specimens which was determined using a metric ruler. Specimens were identified following descriptions of Wehr and Dikmans (1935), Annereaux (1941) and Caballero (1945) for adult *O. cervipedis* and that of Hibler (1965) for microfilaria. Raw data are given in Appendices 3, 4 and 5.

B. Results

1. Description of Adult

Adults show characteristics of members of the genus *Onchocerca*, and are filiform and tapered at both ends (Figure 5); with fine transverse striations on cuticle; pronounced swelling at the nerve ring (Figure 6); oral opening simple, esophagus long and narrow, intestine only slightly wider.

Measurements of diagnostic characters are given for female and male worms in Table I and II (raw data see Appendices 3 and 4), where

TABLE I

MEASUREMENTS OF SOME DIAGNOSTIC CHARACTERISTICS OF FEMALE *ONCHOCERCA CERVIPEDIS*

Diagnostic Character	This Study			Wehr and Dikmans (1935)	Annereaux (1941)	Caballero (1945)
	n = 10			n = ?	n = 6	n = ?
	host = *Alces alces andersoni*			host = *Odocoileus virginianus* *O. columbianus* *O. hemionus* (probably)	host = *O. hemionus*	host = *O. columbianus* *O. hemionus* *O. virginianus* *Cervus canadensis* *Antilocapra americana*
	Means	S.D.	Range			
Total Length (mm.)	186.8	13.4	164- 202	180- 200	140- 220	158- 200
Max. body width (µm.)	399.0	43.5	314- 440	416	345	368
Nerve ring to anterior (µm.)	579.0	34.1	525- 630	327	335	328
Esophagus to anterior (µm.)	1658.0	299.6	1134-2016	1100-1530	1520-1560	1592
Vulva to anterior (µm.)	1675.0	299.9	1092-2121	1250-1530	1129	1028
Anus to posterior (µm.)	537	138.4	336- 756			304

TABLE II

MEASUREMENTS OF SOME DIAGNOSTIC CHARACTERISTICS OF MALE *ONCHOCERCA CERVIPEDIS*

	This Study			Wehr & Dikmans (1935)	Annereaux (1941)	Caballero (1945)
	n = 7			n = ?	n = 2	n = ?
	host = *Alces alces andersoni*			host = *Odocoileus virginianus* *O. columbianus* *O. hemionus*	host = *O. hemionus*	host = *O. columbianus* *O. hemionus* *O. virginianus* *Cervus canadensis* *Antilocapra americana*
Diagnostic Character	Mean	S.D.	Range			
Total length (mm)	57.0	3.6	52- 63	55- 60	40	55.0-64.8
Ant. max. width (µm.)	224.0	8.9	213- 241	-	224	-
Mid. max. width (µm.)	232.0	5.4	224- 234	228	211	240
Nerve ring to anterior (µm.)	306.0	12.8	287- 308	320	268	272
Esophagus to anterior (µm.)	1463.0	320.2	934-1595	700	1070	1260
Long spicule length (µm.)	226.0	8.5	217- 238	245	226- 245	256
Short spicule length (µm.)	137.0	6.5	126- 147	112	112- 120	132
Anus to posterior (µm.)	181.0	15.6	168- 203	145	155- 180	180

Figure 5. Male and Female *Onchocerca cervipedis*: f - female, m - male.

Figure 6. Anterior Extremity of Female *Onchocerca cervipedis*, dorsal view: e - esophagus, nr - nerve ring.

Figure 7. Vulva Region of Female *Onchocerca cervipedis*, doral view: i - intestine, v - vulva.

Figure 8. Posterior Extremity of Female *Onchocerca cervipedis*: c - anus.

Figure 9. Posterior Extremity of Male *Onchocerca cervipedis*, lateral view: ap - anal papillae, cp - caudal papillae, ls - long spicule, ss - short spicule.

Figure 10. Anal Region of Male *Onchocerca cervipedis*, lateral view: ap - anal papillae, pap - post anal papillae.

Figure 11. Microfilaria of *Onchocerca cervipedis*.

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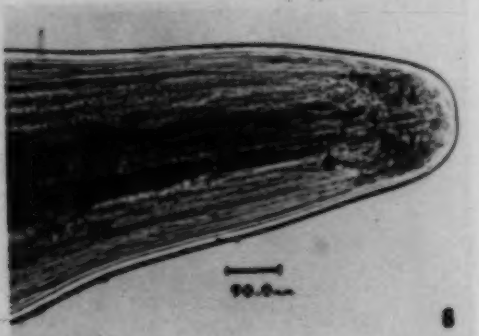
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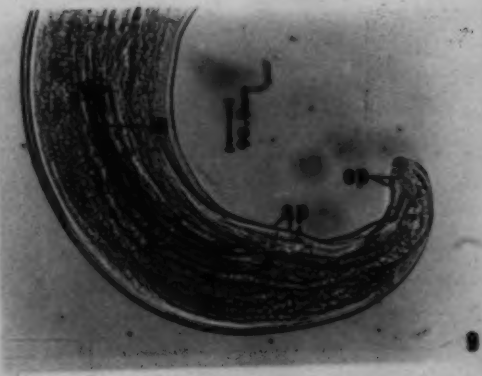
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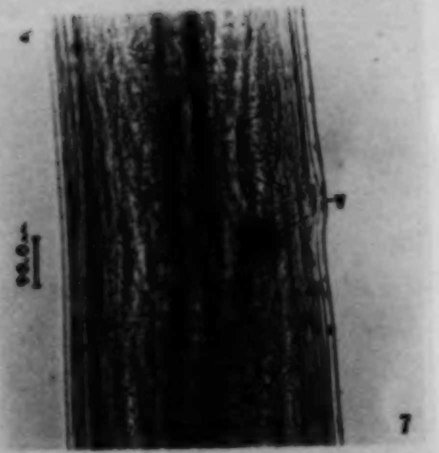
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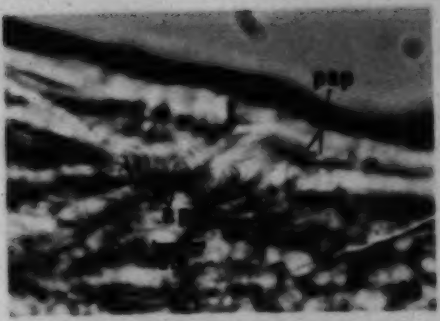
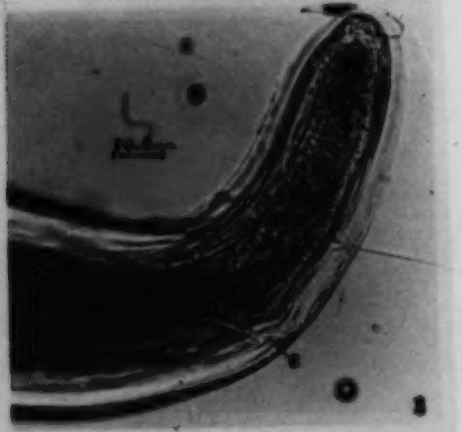

pap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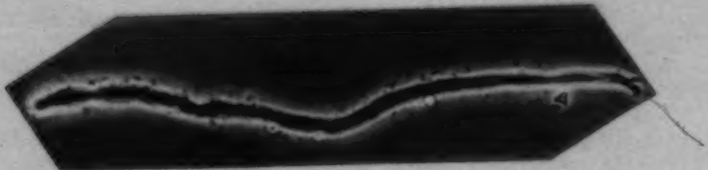


they are compared to similar measurements given by Wehr and Dikmans (1935), Annereaux (1941) and Caballero (1945).

a. Females

Females 186.8 mm long, maximum width 399 μm. (Table I). Nerve ring 579 μm. from the anterior extremity (Figure 6). Esophagus 1658 μm. long. Vulva located near junction of esophagus and intestine, 1675 μm. from anterior extremity (Figure 7). Cloaca 537 μm. from posterior extremity (Figure 8).

b. Males

Males 57 mm long (Table II). Width at dilation 224 μm, maximum mid-body width 232 μm. Nerve ring located 306 μm. from anterior extremity. Esophagus 1.46 mm long. Spicules unequal and dissimilar (Figure 9). Long spicule 226 μm long, with heavily chitinized walls and diagonal chitinized ridge in middle. In lateral view tapered distally to a fine curved point (Figure 9). Short spicule 136 μm. long, with thick chitinized walls. Anterior extremity concave with heavy chitinized edges in lateral view. Short spicule tapered distally and expanded to spatulate end with rounded edges. Papillae apparent in oblique lateral-ventral view. Two pair of adanal papillae along ventral mid line. Four pair of papillae in close grouping lateral to anus, and one pair posterior (Figure 10). One large pair of papillae positioned near tip of tail (Figure 9). Tail 181 μm. long.

2. Description of Microfilariae

Microfilariae, like the adults, are filiform and transversely striated (Figure 11). Rounded anteriorly and tapered posteriorly. No sheath apparent. Microfilaria 270 μm. long and 7 μm. at maximum width. Measurements of microfilariae diagnostic characters are in Table III (raw data see Appendix 5), where they are compared to similar measurements given by Hibler (1965).

3. Diagnosis

The legworm of moose from the Swan Hills agree in most essential characters with those described for O. cervipedis by Wehr and Dikmans (1935), Annereaux (1941), Caballero (1945), and Hibler (1965). The adult legworm characters agree in total length, maximum width, distance of esophagus to anterior extremity and distance from anus and cloaca to posterior extremity. The distance from the nerve ring to anterior extremity and the long spicule length in male legworm in this study also are in agreement with data reported in other studies, as is the maximum width of the microfilaria (Tables I, II and III). Discrepancies are as follows: in the distance of the nerve ring to the anterior extremity in the female legworm, that is 1675 micrometers in this study compared to 1129 micrometers in specimens from mule deer (Annereaux, 1941) (Table I), the longer short spicule length in the male (137 μm. this study to 132 μm. Caballero (1945)) (Table II) and the longer microfilaria (270 μm. this study to 224 μm.).

TABLE III

MEASUREMENTS OF SOME DIAGNOSTIC CHARACTERISTICS OF MICROFILARIAE OF *ONCHOCERCA CERVIPEDIS*

	This Study			Hibler (1965)	
	n = 16			n = 20	
	host = *Alces alces andersoni*			host = *Odocoileus hemionus* *O. virginianus*	
Diagnostic Character	Mean	S.D.	Range	Mean	Range
Total length (µm.)	270.0	30.5	224-322	224	209-238
Max. width (µm.)	6.6	0.6	5.8-7.3	6	5- 7

V. ADULT ONCHOCERCA CERVIPEDIS IN MOOSE

A. Materials and Method

Two collecting methods were used to determine prevalence of *O. cervipedis* in moose of the Swan Hills and its distribution in this host in relation to host age and sex.

Firstly, a hunter check station was operated for 57 hunting days from September 20 to November 15, 1975, in cooperation with Alberta Department of Recreation, Parks and Wildlife. It was located 1.5 km. south of Fort Assiniboine along Highway 18, the main highway into the study area from the more densely populated areas to the south (Figure 1). Signs requesting hunters to report were placed along the highway approximately at one km. and at 30 metres before each entrance to the hunter check station.

Hunters were informed verbally of the purpose of the check station and were provided with a form letter outlining the purpose and parts of the moose requested (Appendix 6). They were asked to submit all four legs below the tibio-tarsal joint, and the head and hide of any big game animal taken. Rarely were submissions complete (n=1). All or some legs (n=42) and lower jaw (n=17) were most commonly submitted, but the head (n=12) and hide (n=1) were usually left at the kill site or kept by the hunter. However, portions of a total of 43 moose were submitted by hunters.

Secondly, I was notified by the Fish and Wildlife Division of the location of moose killed in tagging operations (n=2). These were field dressed and transported to the Parasitology laboratory on the 9th Floor of the Biological Sciences Building, University of Alberta, for examination.

Each moose was assigned an identification number and information about the animal was recorded on standard data sheets (Figure 12). Identification labels were attached to each separate part of the specimen. The lower jaw was removed, labelled and submitted to Fish and Wildlife Division for age determination (n=21), while the remainder of the sample was examined in the field or transported to the University of Alberta, frozen and stored for later examination.

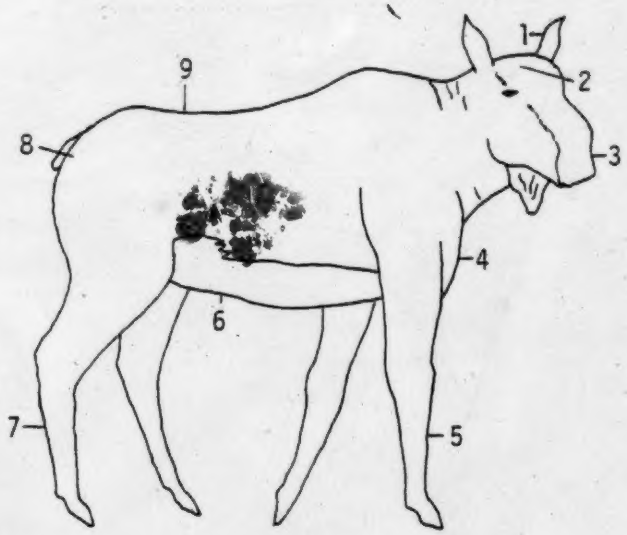
The tendons of legs were cut and removed from tarsal bones to expose underlying connective tissue. These freshly skinned areas were examined for adult *O. cervipedis*. Worm location was mapped (Figures 13 and 14) and the sex and condition of worm noted. Worms were removed from the connective tissue using needle point forceps, dissecting needle and scalpel, and placed in labelled vials containing 70% ethanol, to be stored for identification. A total of 45 moose was examined.

B. Results

The forty-five moose examined for adult *O. cervipedis* consisted of 3 complete moose, 42 sets of legs (36 - all 4 legs, 5 - 2 legs, 1 - one leg), 11 heads (17 lower jaws) and one hide.

Adult *O. cervipedis* occurred in 64.0% (29) of the moose examined. Twenty-six males and 3 females were infected (details for each moose are shown in Appendix 7). This disproportionate host-sex ratio did not permit a conclusion on any host-sex preference by the legworm.

All adult legworms were located in the subcutaneous connective



SPECIMEN NUMBER

Date -
Time -
Observer -
Game Species - Moose Mule Deer Other
Sex
Limbs -
    Fore - 1 Both
    Hind - 1
Hide - Yes No
Head - Yes No
Tooth - Yes No

Date of kill -
Time of kill -
Location of kill -

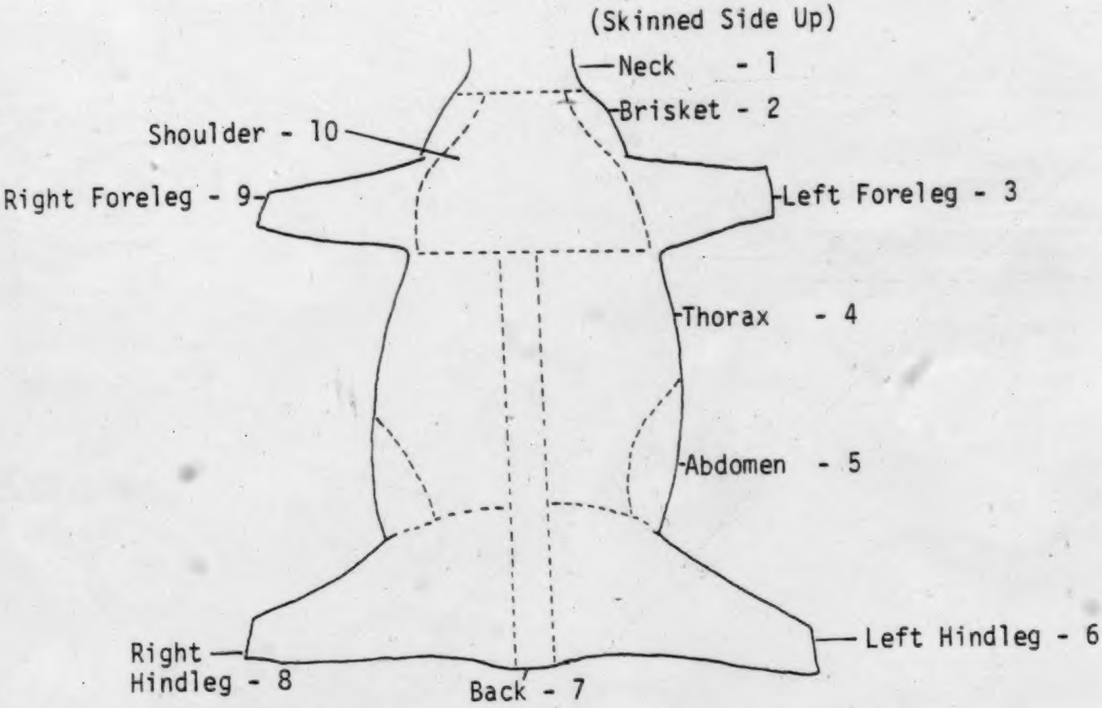
No. of hunters in party -

SKIN SAMPLES

============

Area	Yes	No
1) Ear		
2) Head (area between ears)		
3) Nose (distal to nasal bone)		
4) Brisket		
5) Fore leg (tibia tarsus)		
6) Belly (abdominal area)		
7) Hind leg (tibia tarsus)		
8) Rump		
9) Back (lumbar region)		

Figure 12. Moose Data Sheet.


(Skinned Side Up)
Neck - 1
Brisket - 2
Shoulder - 10
Right Foreleg - 9
Left Foreleg - 3
Thorax - 4
Abdomen - 5
Left Hindleg - 6
Right Hindleg - 8
Back - 7

Adult Worm Data Sheet

Specimen No.
Date of Observation
Date of Kill
Location of Kill
Game Species Moose______ Mule Deer ______ Other______
Sex Male ______ Female ______

Location of worms	No. of worms	Sample
1. Neck		
2. Brisket		
3. Left Foreleg		
4. Thorax		
5. Abdomen		
6. Left Hindleg		
7. Back		
8. Right Hindleg		
9. Right Foreleg		
10. Shoulder		

- Record approximate location of worms on host.
- Sample, label (Specimen No., location on host) and preserve.
- For Nodules note number of worms per nodule. STORE in alcohol noting specimen no., location on host.

Nodules	Location on host	No./nodule

Figure 13. Adult *Onchocerca cervipedis* Location Data Sheet No. 1.

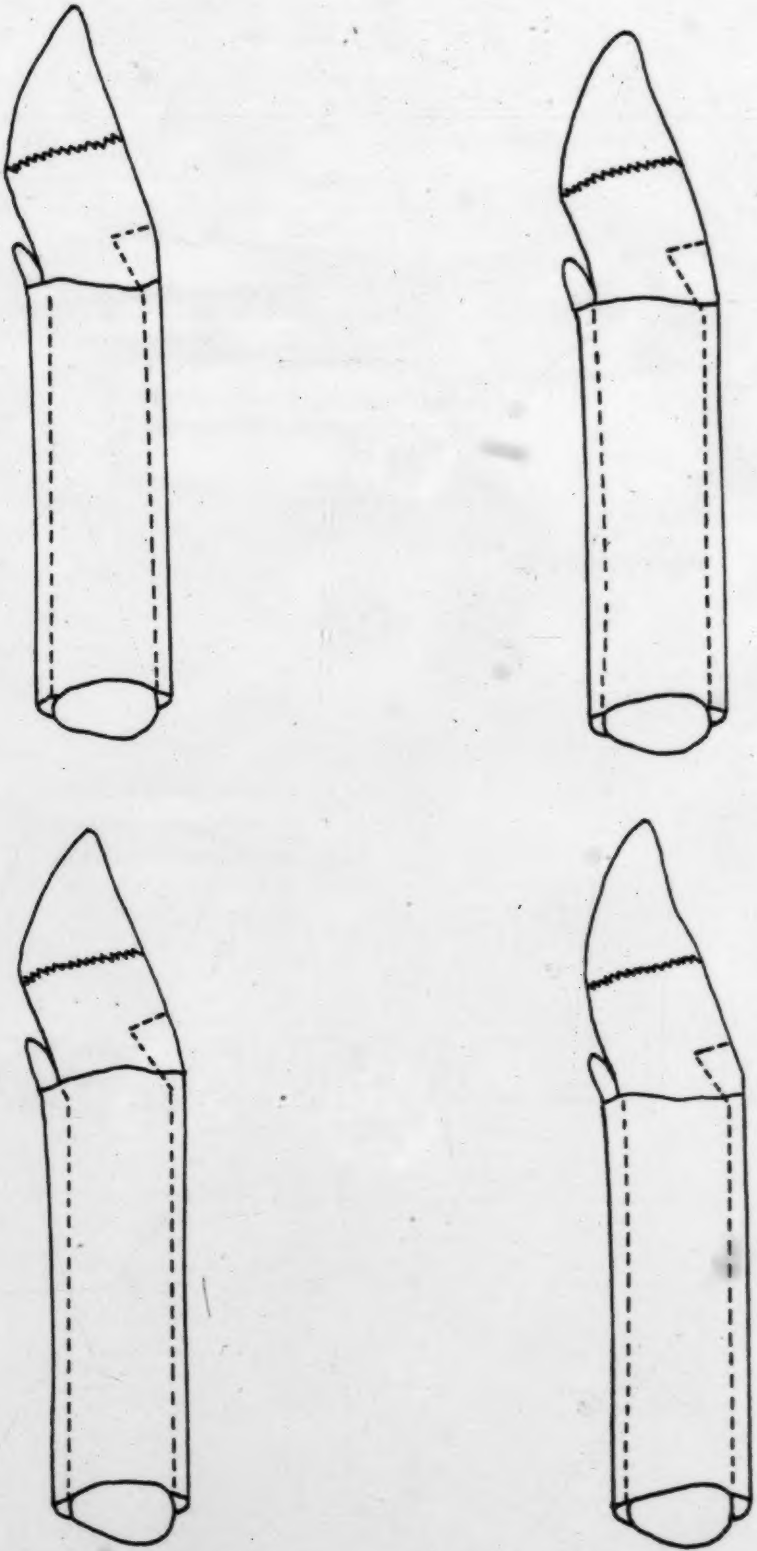


Figure 14. Adult Onchocerca cervipedis Location Data Sheet No. 2.

tissue beneath the skin of a leg, except for two legworms located in the brisket and belly area of a heavily infected moose (moose number 1, Appendix 8). The distribution of adult legworms in the limbs was not even. Eighty per cent (475) of adults were found in the lower fore legs and 20.0% (118) in the lower hind legs (Figure 15). In these legs, 38.0% (223) of the legworms were located in the tibio-tarsal joint area, 56.0% (334) in the tarsus and 6.0% (36) in the phalanges area (Figure 16). In the tarsus and phalanges area, 56.0% (207) of the adult legworms were adjacent to the bone, while 44.0% (163) were associated with tendons, with 33 of these legworms under tendons (details see Appendix 8).

A moose calf (n=1) and the yearlings (n=2) were not infected, while 71.0% (15) of the older moose were infected (Table IV). Abundance of adult legworms shows a positive linear relationship to age of moose (correlation coefficient $r=0.75$) (Figure 17).

Only 13 of 595 adult _O_. _cervipedis_ recovered in this study were males giving a sex ratio of 2.2:100. Adult legworms were found in an extended or coiled position (Figures 18 and 19). Coiled worms were found loose in the subcutaneous connective tissue or surrounded by fibrous tissue which forms a nodule. (Figure 19). Calcification was apparently not influenced by host age (correlation coefficient $r=0.13$) or abundance of _O_. _cervipedis_ (correlation coefficient $r=0.01$) in the host (Table V). Chi-squared analysis showed no statistical significant difference, ($x^2 = 3.45$ $p<0.05$), in the coiled or extended state of legworms from normal or calcified condition.

Nodules contained from one to seven legworms (Table VI); most had only one. Only one male legworm was ever recovered from a nodule.

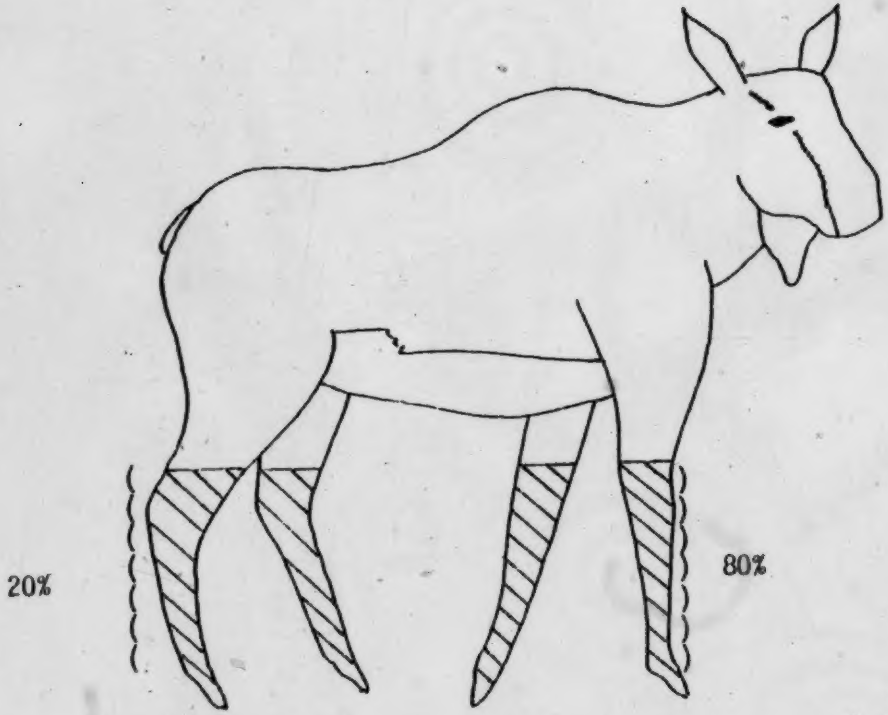


Figure 15. Distribution of Adult *Onchocerca cervipedis* in Moose.

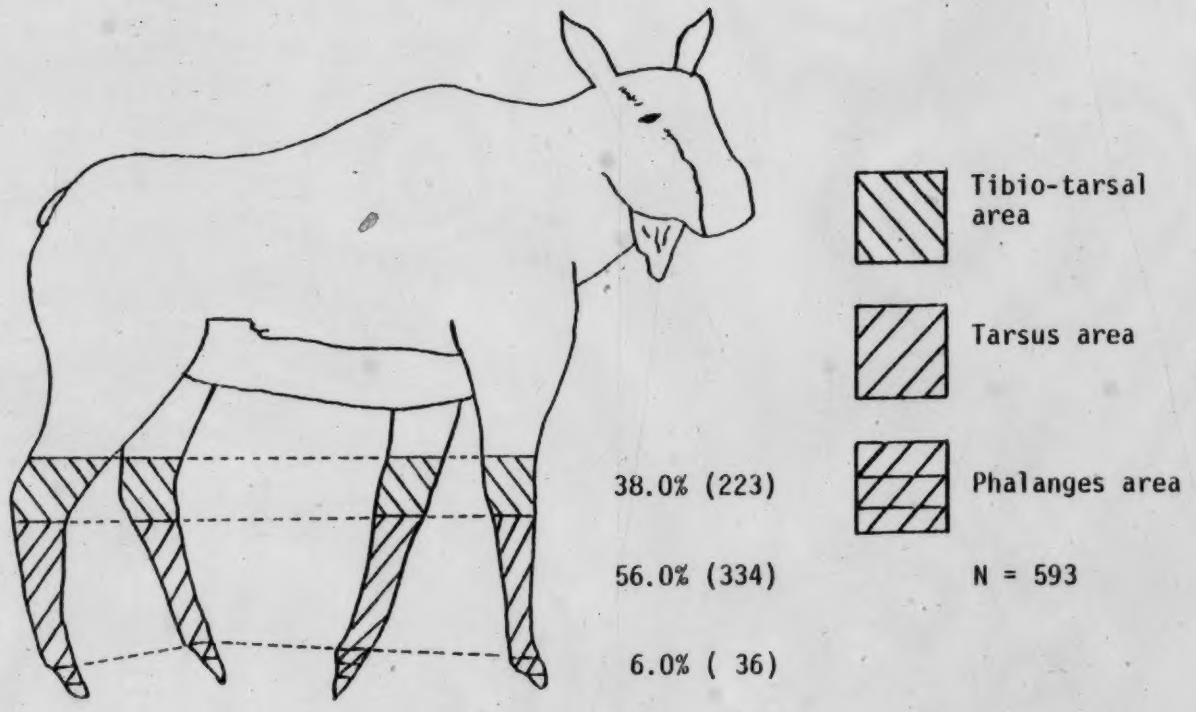

38.0% (223)
56.0% (334)
6.0% (36)
Tibio-tarsal area
Tarsus area
Phalanges area
N = 593

Figure 16. Detailed Distribution of Adult Onchocerca cervipedis in Moose.

TABLE IV

DISTRIBUTION OF *O. CERVIPEDIS* IN RELATION TO MOOSE AGE

	Moose Age (years)	Number of Adult Worms		
		Lower Fore Limb	Lower Hind Limb	Total
	0.5	0	0	0
	1.5	0	0	0
	1.5	0	0	0
	2.0	0	0	0
	2.5	0	0	0
	2.5	0	0	0
	2.5	1	0	1
	3.5	2	1	3
	3.5	7	0	7
	4.5	22	0	22
	5.5	1	0	1
	5.5	4	0	4
	5.5	4	0	4
	5.5	2	0	2
	5.5	14	10	24
	6.5	5	0	5
	6.5	2	3	5
	8.5	3	0	3
	8.5	26	6	32
	9.5	11	4	15
	13.5	44	9	53
Total N=21		148	33	181
% of Total		81.8	18.2	100

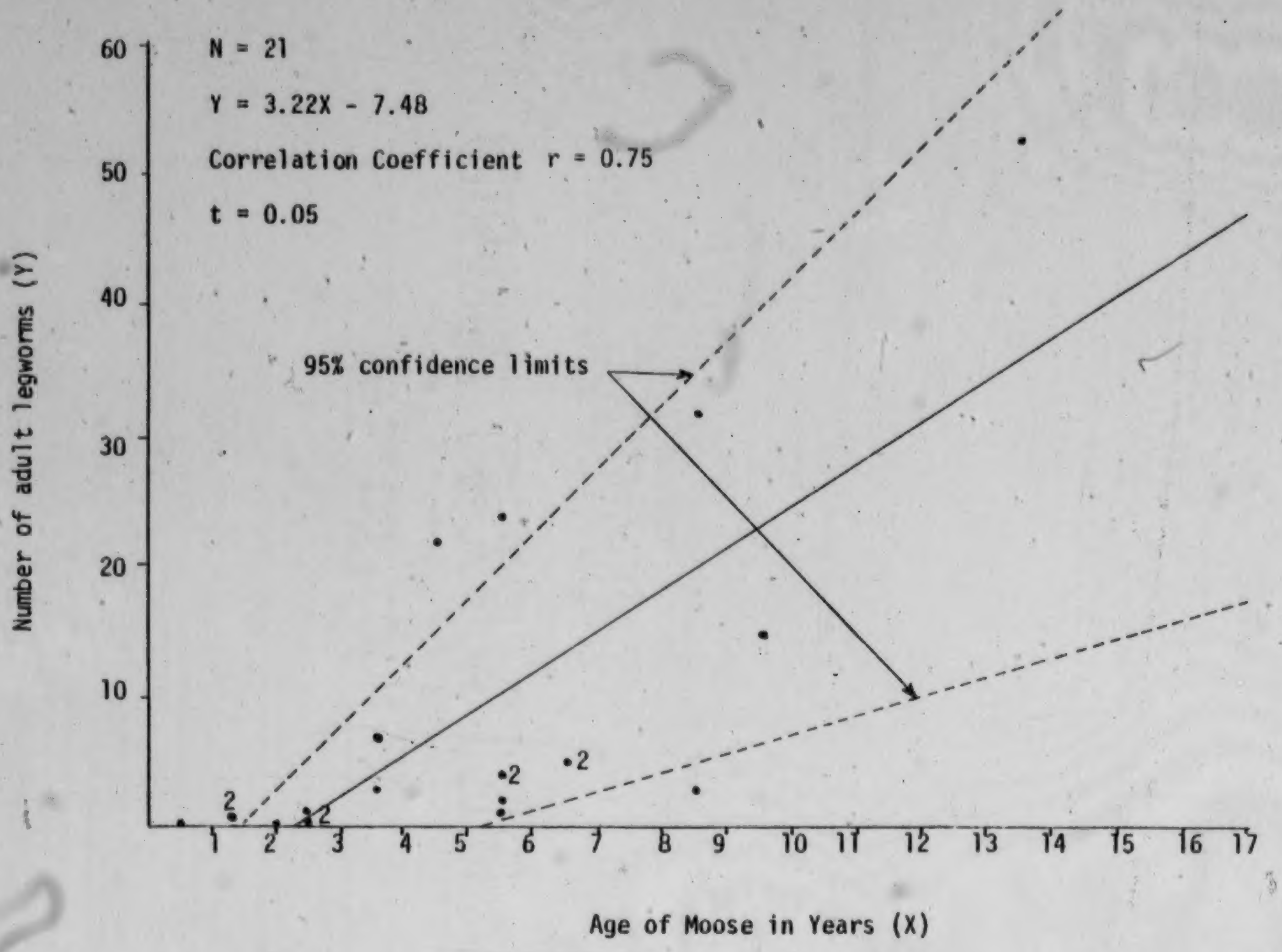
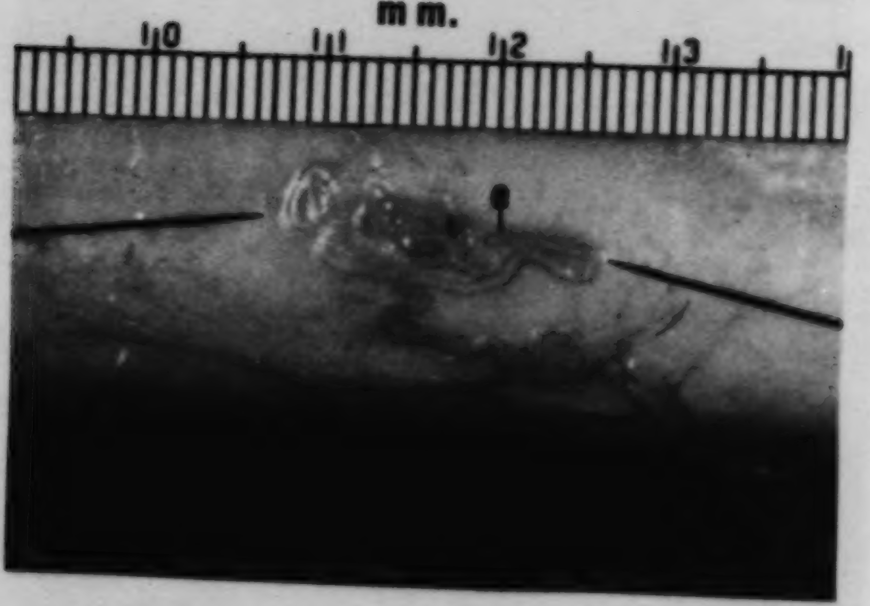


Figure 17. Regression of Adult *Onchocerca cervipedis* Abundance on Age of Moose.

Figures 18 and 19. In Situ Condition of Adult *Onchocerca cervipedis*.
Figure 18. Extended: e - extended.
Figure 19. Coiled: c - coiled, n - nodule.


mm.
10
11
12
13
e

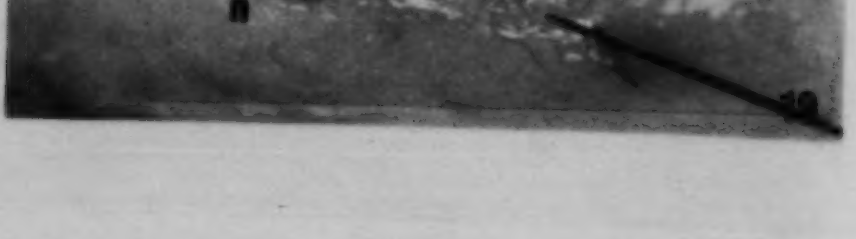

mm.
n
c
10

TABLE V

IN SITU CONDITION OF ADULT *O. CERVIPEDIS* IN MOOSE

	Moose Age (years)	Condition of Adult *O. cervipedis*				Total Number of Adults
		Normal		Calcified		
		extended	coiled	extended	coiled	
	2.5	0	1	0	0	1
	3.5	0	4	1	2	7
	4.5	4	7	8	3	22
	5.5	4	0	0	0	4
	5.5	3	1	0	0	4
	5.5	1	0	0	0	1
	5.5	2	21	0	1	24
	5.5	2	0	0	0	2
	6.5	1	1	3	0	5
	6.5	2	3	0	0	5
	8.5	1	16	6	9	32
	8.5	0	3	0	0	3
	9.5	13	2	0	0	15
Total N=12		33	59	18	15	125
% of Total		26.4	47.2	14.4	12.0	

TABLE VI

NUMBER OF ADULT O. CERVIPEDIS IN NON-CALCIFIED NODULES IN MOOSE

Number of Nodules Examined	Number of Adult Worms Per Nodule	
	Female	Male
1	1	1
1	7	0
1	5	0
2	3	0
6	2	0
27	1	0

VI. MICROFILARIA OF *ONCHOCERCA CERVIPEDIS* IN MOOSE

A. Materials and Methods

Sixteen live-trapped moose and 21 moose killed within 24 hours before examination were sampled for microfilariae distribution. Killed moose were sampled from September 12 to October 12, 1975; while live moose were trapped from June 1 to August 15, 1976. The trapping was conducted by wildlife biologists from Alberta Department of Recreation, Parks and Wildlife, Fish and Wildlife Division as part of a tagging operation. Nine moose traps (LeResche and Lynch, 1974) were positioned in the study area along game trails leading to mineral licks (Figure 1).

Trapped moose were immobilized with M-99® (Cyanamid of Canada Limited) injected intermuscularly by a tranquilizing gun. Skin biopsies were taken from downed moose as was information regarding their age and sex. Time, date of sampling and weather conditions were also recorded. After 15 minutes an intravenous injection of the antidote M50-50® (Cyanamid of Canada Limited) revived the moose and it was released.

The skin biopsies were taken from up to nine standard sites on the moose (Figure 20). Biopsy site 7 was located in an area which in the summer developed into an open sore, characterized as a hairless calloused area with small lesions. No attempt was made to consistently sample one particular side of the moose. Restrictions on the number and/or location of samples occurred when the hide of hunter-killed moose was wanted for tanning by the hunter or when live trapped moose were under severe stress due to handling.

Site 9 - antler in velvet
Site 7 - sore area

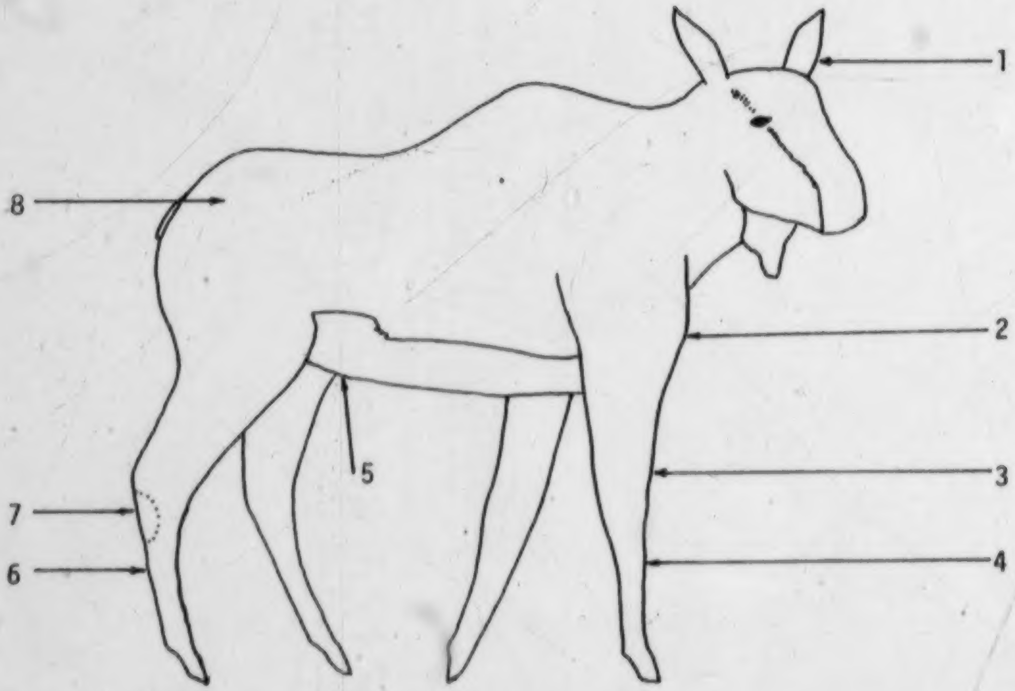


Figure 20. Biopsy Site for *Onchocerca cervipedis* Microfilaria Presence in Moose.

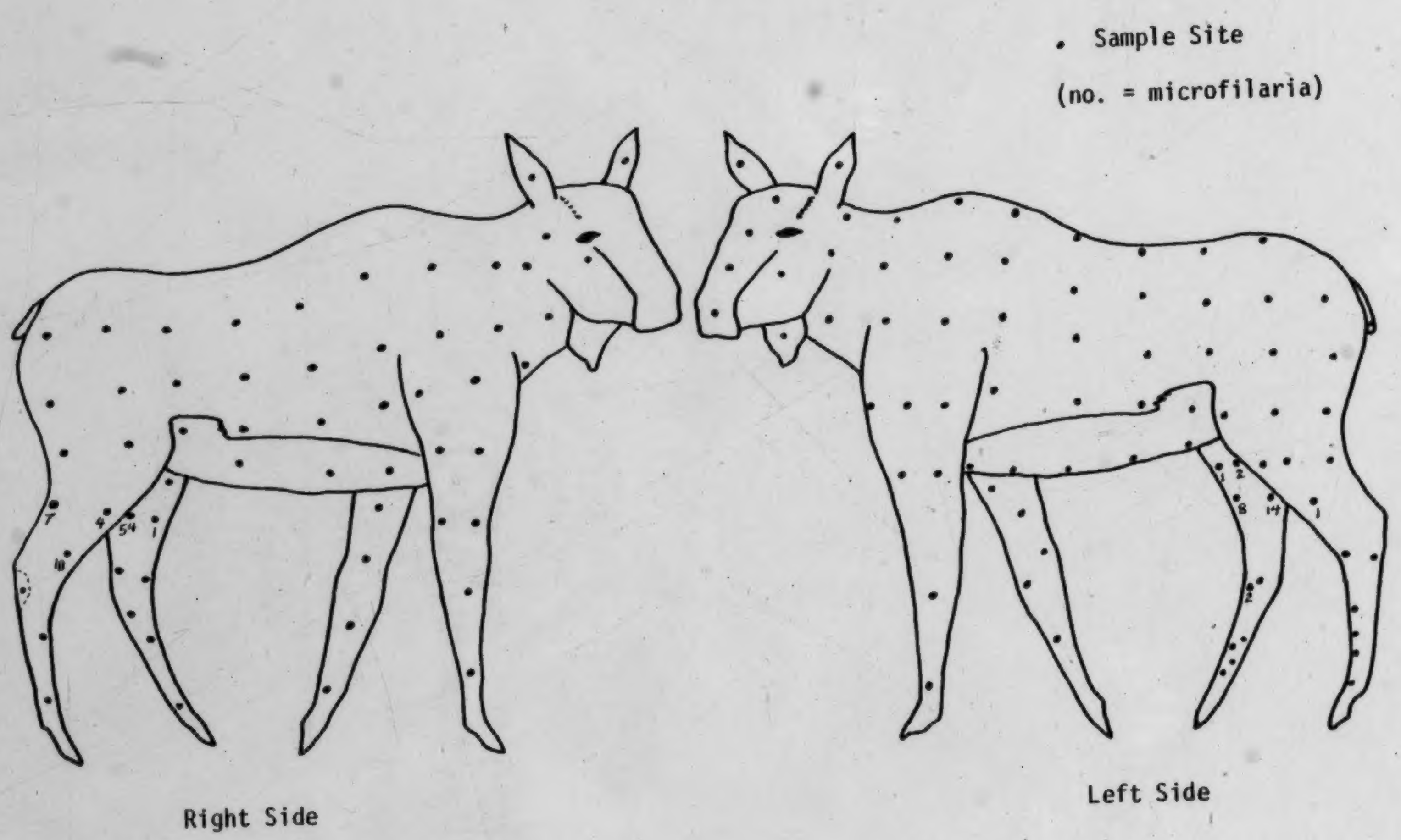
On July 2, 1977 a 2.5 year old female moose was killed and sampled extensively for microfilariae. A grid with 20 centimetre spacing was drawn on the body surface using a chalk line and metric rule. Two skin biopsies were taken at each of the 135 sample sites to give a total of 270 biopsies (Figure 21). The number of microfilariae given for each biopsy site is the sum of the two biopsies.

To take a biopsy the hair overlying the sample site was first removed with scissors; then a 0.4 centimetre diameter core of dermal tissue was removed using a biopsy punch. The depth of the skin sample varied with the location on the moose and was thickest on the back, abdomen and brisket, and thinnest on the ear.

Skin biopsies were placed in labelled glass vials (4 dram snap-on cap), covered with Earle's solution (Humason, 1967) and stored for 24 hours. The contents of the vial were placed in a petri dish and scanned with the aid of a binocular microscope (Wild M5) at 100 power for microfilariae which were counted if present. Sample specimens were placed on a microscope slide and examined at 200 power using a monocular compound microscope (Wild, M11). General morphological features (shape, size, transverse striated cuticle) were used for field identification. The microfilariae were returned to the labelled vial, 70% ethanol added and stored for laboratory identification.

B. Results

Skin biopsy samples were taken from 37 moose. Only samples taken from wild trapped moose in mid-June and July 1976 contained microfilariae (Table VII). Of the 16 moose trapped and sampled during this period, 50.0% (8) were positive for microfilariae, while none of 21 hunter-



• Sample Site
(no. = microfilaria)
7
4
54
1
10
1
2
8
14
1
2
Right Side
Left Side

Figure 21. Distribution of Onchocerca cervipedis Microfilariae in Moose Number 122.

TABLE VII

NUMBER OF MICROFILARIAE OF ONCHOCERCA CERVIPEDIS IN SKIN BIOPSIES FROM MOOSE DURING 1976

	Area Sampled								
			Fore Limb			Hind Limb			
Date Sampled	Ear	Brisket	Upper	Lower	Belly	Lower	Sore	Rump	Antler in Velvet
15-VI -75	0	-	0	-	-	0	-	-	-
16-VI -75	0	-	1	-	0	1	0	-	-
16-VI -75	0	-	0	-	-	1	-	-	-
21-VI -75	0	-	0	-	-	0	-	-	-
21-VI -75	0	-	0	-	-	0	-	-	-
23-VI -75	0	-	0	-	-	0	-	-	-
23-VI -75	0	-	0	-	-	434	-	-	-
29-VI -75	0	0	0	-	-	0	-	0	-
29-VI -76	0	-	1	-	-	17	-	-	-
30-VI -76	0	-	0	-	-	39	-	-	-
1-VII-76	0	-	0	-	-	0	-	-	-
13-VII-76	0	0	0	0	0	0	0	0	0
15-VII-76	0	0	-	0	0	0	1	0	-
16-VII-76	-*	0	0	97	0	0	-	0	-
17-VII-76	0	0	0	-	0	-	0	0	0
18-VII-76	0	0	0	0	0	4	3	0	0
Total	0	0	2	97	0	496	4	0	0
Mean No. Microfilariae	0	0	1	97	0	82.7	2.7	0	0

* - = no sample taken

N = 16

killed moose sampled in September-October (1975) yielded microfilariae, (Appendix 9) even though eight of 15 of these sampled for both adult and microfilarial stages contained adults.

The number of microfilariae recovered varied substantially among individual moose and among biopsy sites (Table VII). Only biopsies from the legs were positive for microfilariae. A total of 83.5% (500 of 599) microfilariae was recovered from the lower hind leg, while 16.5% or 99 were from the fore leg.

Microfilariae were found only in the skin of the hind legs of the two-year-old moose (number 122) sampled extensively in July 1977 (Figure 21). Microfilariae were recovered from dermal tissue samples taken from the ventral aspect of upper and lower hind legs (n=82) and the dorsal aspect of upper hind legs (n=30) of this animal. Microfilariae were more abundant (73.0%) in samples from ventral aspect.

VIII. BLACK FLY ADULTS ATTRACTED TO AND BLOOD FEEDING ON MOOSE

A. Materials and Methods

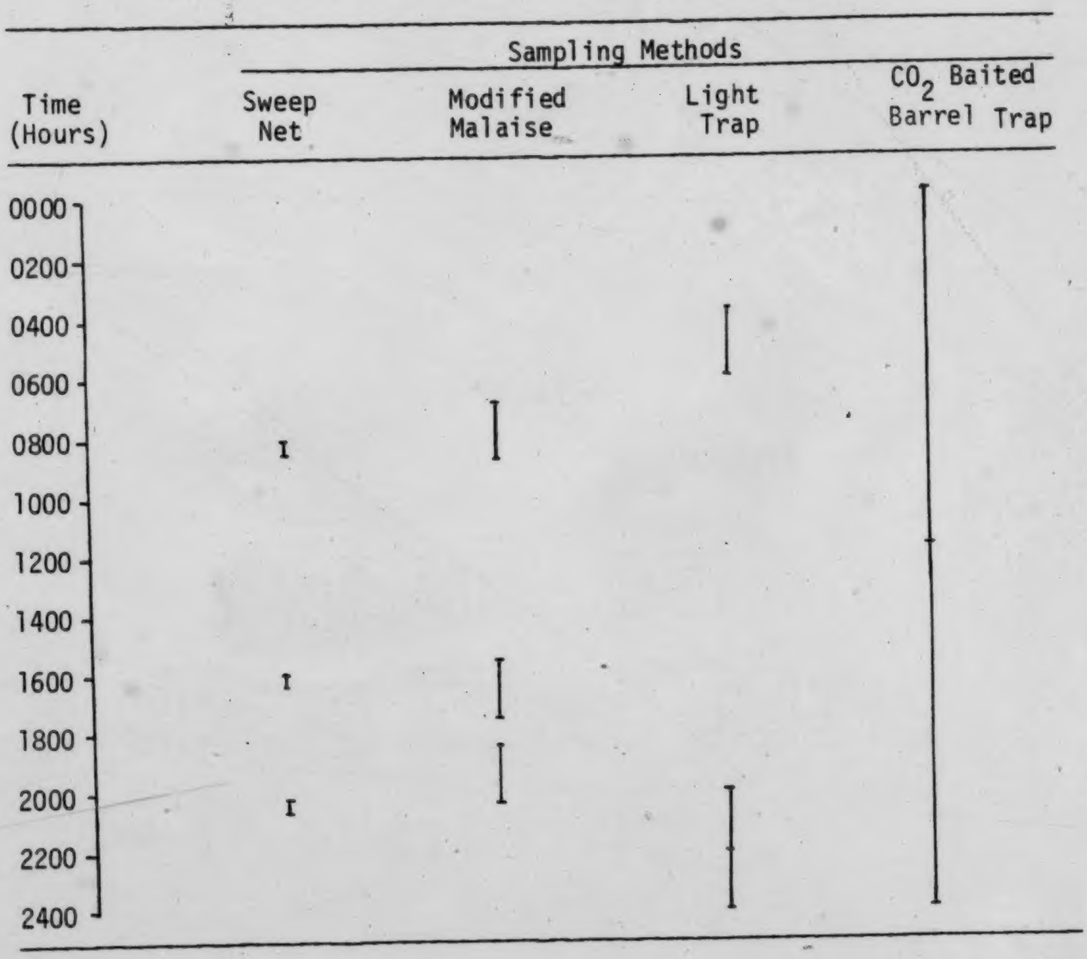
Adults of black fly species attracted to and blood feeding on moose were collected from thirteen wild trapped moose and a penned moose as bait. Observations were made on preferred feeding sites on the host and the host's response to biting fly activity. Wild moose were live trapped and immobilized (see page 26). These moose were swept for black flies using an insect sweep net immediately upon approaching the moose and again just prior to administering the antidote (M50-50 diprenorphine) to the tranquilizing drug. I was the second person to the downed moose and took the initial sweep sample before examination of the moose by the wildlife biologists. Because of the difficulties of that work, the number of sweeps was not standardized.

Individual blood engorging blackflies were picked from downed moose with forceps and a paint brush moistened in alcohol. Each sample was stored in a labelled vial with 70% ethanol. Information recorded included moose identification number, trap number, sampling method, time and date, moose age and sex, and local weather conditions.

In 1976 two orphaned female moose calves (approximately 6 weeks old) were obtained by Dr. W.M. Samuel, University of Alberta, through the Alberta Fish and Wildlife Division. On June 6 a grizzly bear entered the moose pen and killed the first moose calf, but a second

TABLE VIII

SAMPLING SCHEDULE FOR ADULT BLACK FLIES IN 1976



alcohol.

The carbon dioxide baited barrel trap was a 22.7 litre (5 gallon) metal cylinder painted dark blue (Marshall Wells - Boat Blue) and a uniform layer of adhesive material applied to the outer surfaces. Multi-Duty Lithium Grease and Petroleum Jelly were used as an adhesive early in the season with little trapping success; after July 1 an aerosol formulation of Tree Tanglefoot® (The Tanglefoot Company) was used which readily trapped black fly adults. Dry ice in a one-half gallon thermal jug with the pouring spout open was placed in the five gallon container and served as the carbon dioxide attractant source. No attempt was made to regulate the rate of flow of the carbon dioxide. The trap was suspended two metres off the ground. Specimens were removed from the adhesive material with forceps or a paint brush moistened in alcohol. The sampling schedule for this trap was designed around the availability of dry ice which was available every eight days with the dry ice lasting three days. The sampling was conducted for three consecutive days at 1200 and 2400 hours every eight days.

New Jersey Light Traps powered by portable gas generators were suspended two metres above the ground. An incandescent 25 watt light bulb served as a light source. A 2.5 square centimetre piece of Vapona No-Pest Strip® (Shell Chemical Company) placed in the trapping jar, killed the collected insects. A sample consisted of a two-hour sampling period. Breakdown of power generators interrupting the sampling schedule and poor trapping success resulted in the black fly data from this trapping method being excluded from this study.

Samples were placed in labelled vials containing 70% ethanol and stored for identification. Blackfly specimens were identified with the aid of a dissecting microscope (Wild M5). An unpublished taxonomic key by F.J.H. Fredeen (Simuliidae Check List of Species in Manitoba, Saskatchewan and Alberta) was the major key used, but published works by Peterson (1970), Stone and Jamnback (1955) and Abdelnur (1968) were also used. Selected specimens of each species were submitted to Dr. R.V. Peterson, Research Branch, Biosystemstics Research Institute, Agriculture Canada for confirmation or identification. Voucher specimens have been deposited in the Strickland Museum, Department of Entomology, University of Alberta.

B. Results

Adults of twenty-one black fly species (Table IX) were collected and identified from the study site during 1976 and 1977. Seventeen of these species have been confirmed by Dr. R.V. Peterson, Agriculture Canada. Simulium euryadminiculum Davies and Simulium jenningsi Malloch had not previously been reported in Alberta.

Adults of thirteen species were common to both forest and muskeg communities while those of two species were unique to the forest community and those of six species unique to the muskeg community (Table X). Species abundance and seasonal activity are presented in Figures 22 to 52. The Simulium venustum Say and Simulium verecundum Stone and Jamnback species complexes were dealt with as S. venustum.

Adults of eight black fly species were considered abundant. In decreasing order these were, adults of: Simulium venustum Say, Simulium decorum Walker, Simulium pugetense Dyar and Shannon, Simulium arcticum Malloch, Simulium latipes (Meigen), Simulium meridionale Riley, Simulium euryadminiculum Davies and Simulium furculatum (Shewell).

TABLE IX

FEMALE BLACK FLY SPECIES COLLECTED 1976-1977

S. aureum Fries complex*

S. arcticum Malloch*

S. croxtoni Nickolson and Mickel*

S. decorum Walker*

S. euryadminiculum Davies*

S. furculatum (Shewell)*

S. jenningsi Malloch*

S. latipes (Meigen)

S. luggeri Nicholson and Mickel*

S. meridionale Riley*

S. pugetense (Dyar and Shannon)

S. rugglesi Nickolson and Mickel*

S. transiens Rubzov

S. venustum/verecundum Say/Stone and Jamnback*

S. vittatum Zetterstedt*

P. decemarticulatum (Twinn)*

P. formosum Shewell*

P. fulvum (Coquillett)*

P. exigens Dyar and Shannon

P. pleurale Malloch

Cnephia taeniatifrons (Enderlein)*

---

*Confirmed by R.V. Peterson, Agriculture Canada.

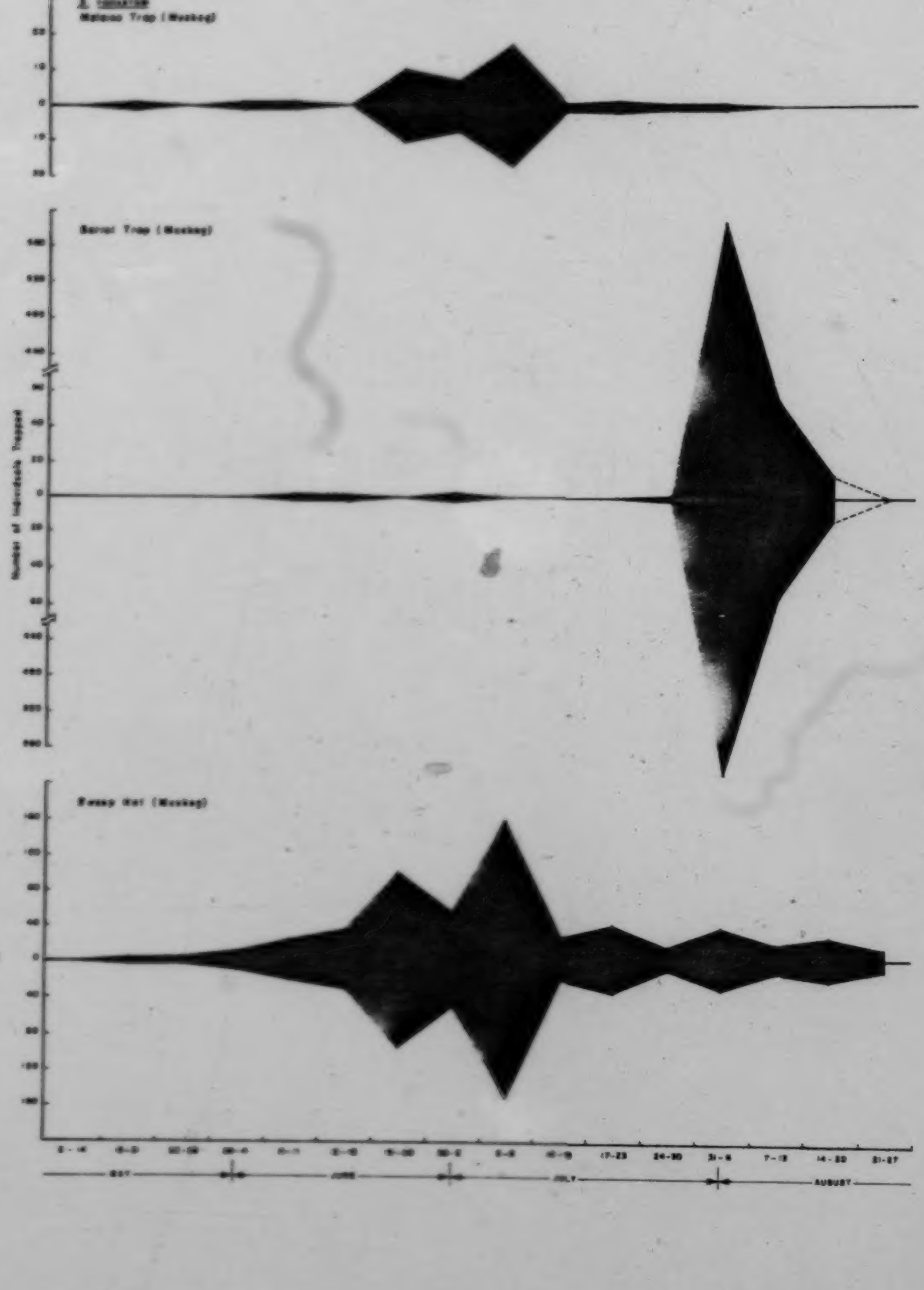
TABLE X

BLACK FLY SPECIES FOUND IN THE FOREST AND MUSKEG COMMUNITIES, SWAN HILLS

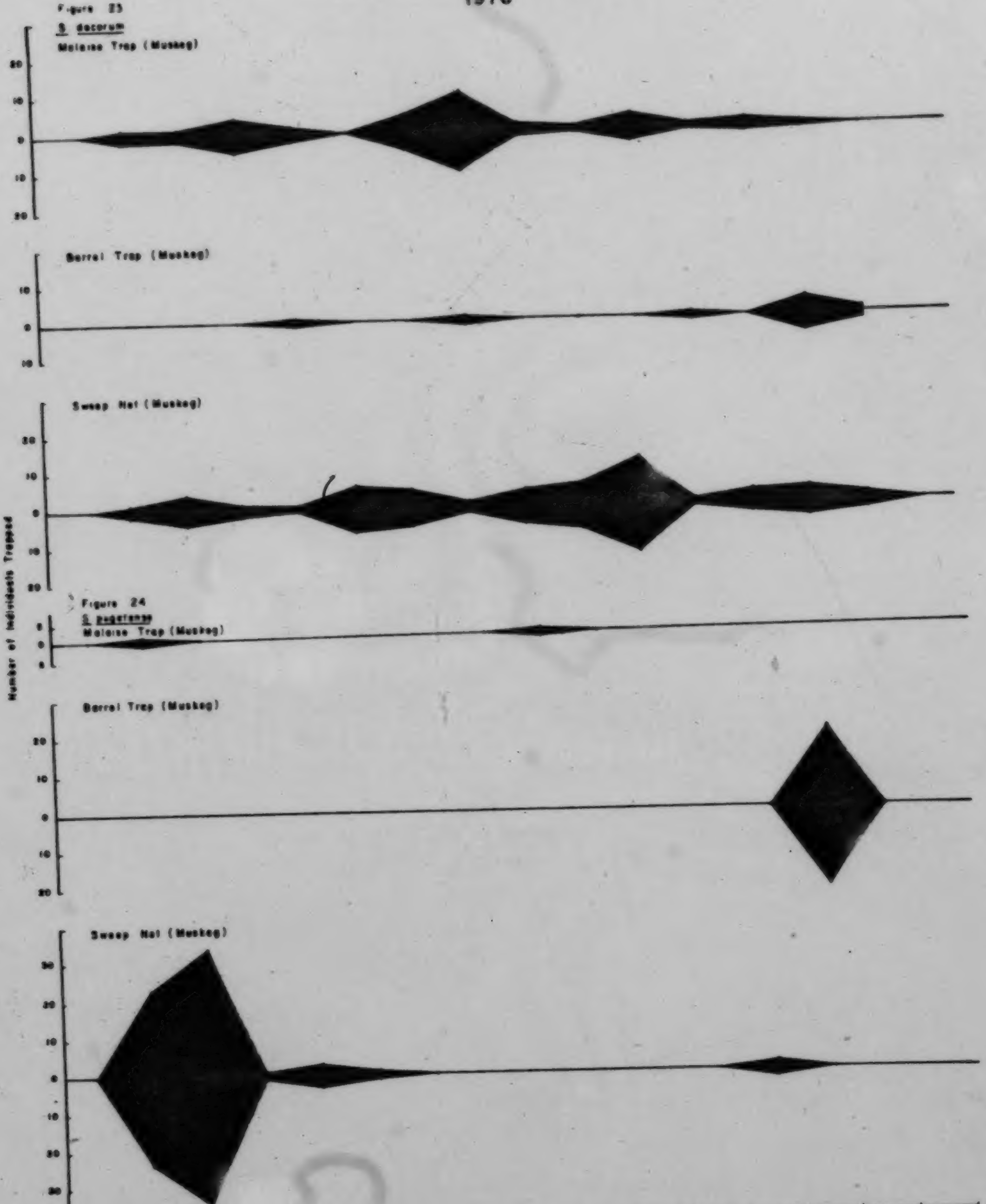
SPECIES FOUND IN:		
Muskeg Community	Forest Community	Both Communities
S. croxtoni		*S. aureum*
S. furculatum	*P. pleurale*	*S. arcticum*
S. rugglesi	*P. formosum*	*S. decorum*
S. transiens		*S. euryadminiculum*
P. exigens		*S. latipes*
C. taeniatifrons		*S. luggeri*
		S. meridionale
		S. pugetense
		S. venustum/*S. verecundum*
		S. vittatum
		P. decemarticulatum
		P. fulvum

ADULT BLACK FLY ACTIVITY
1976

Figure 22



ADULT BLACK FLY ACTIVITY
1976



7

ADULT BLACK FLY ACTIVITY
1976

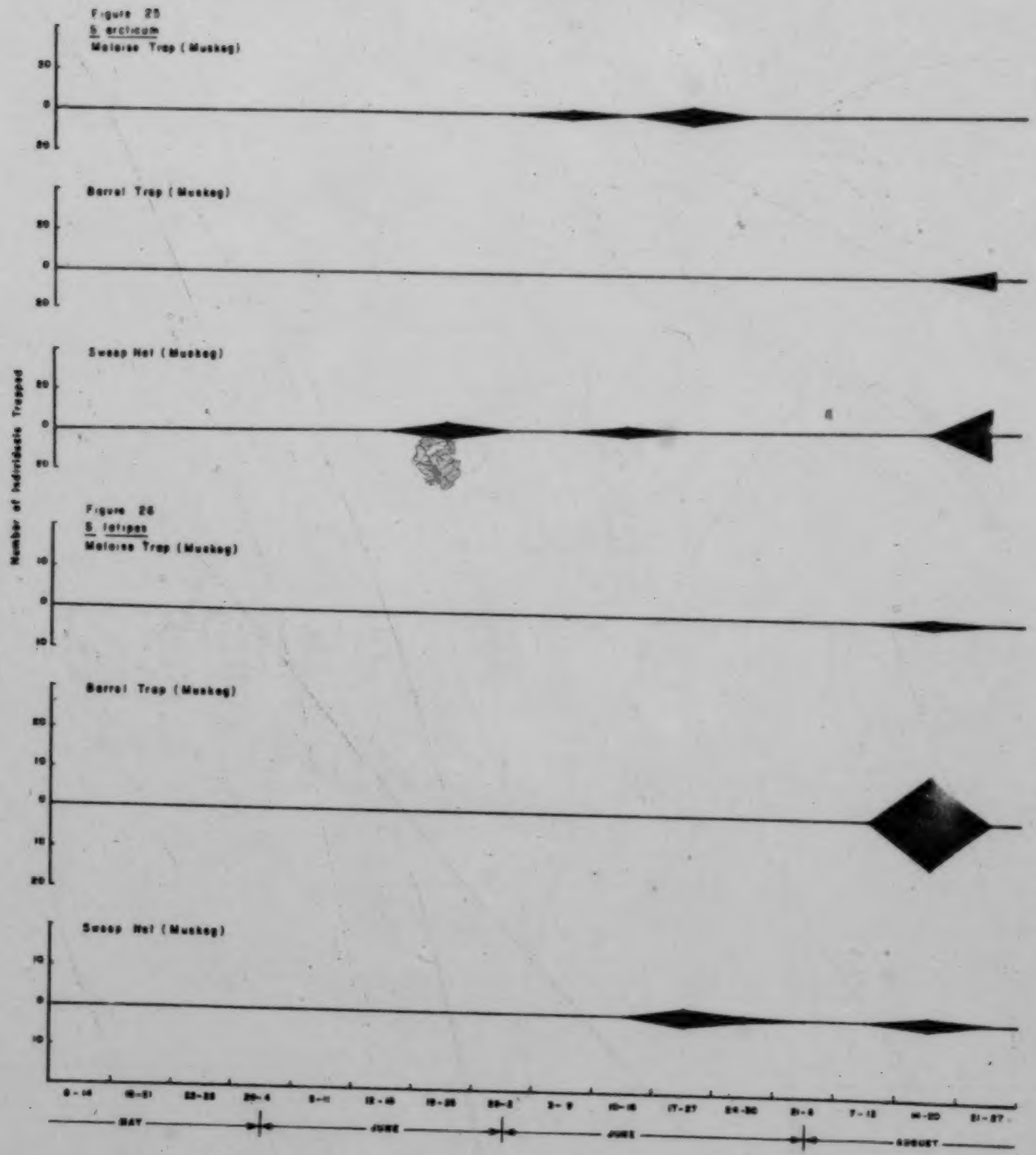


Figure 25
S. arcticum

Figure 26
S. latipes

ADULT BLACK FLY ACTIVITY
1976

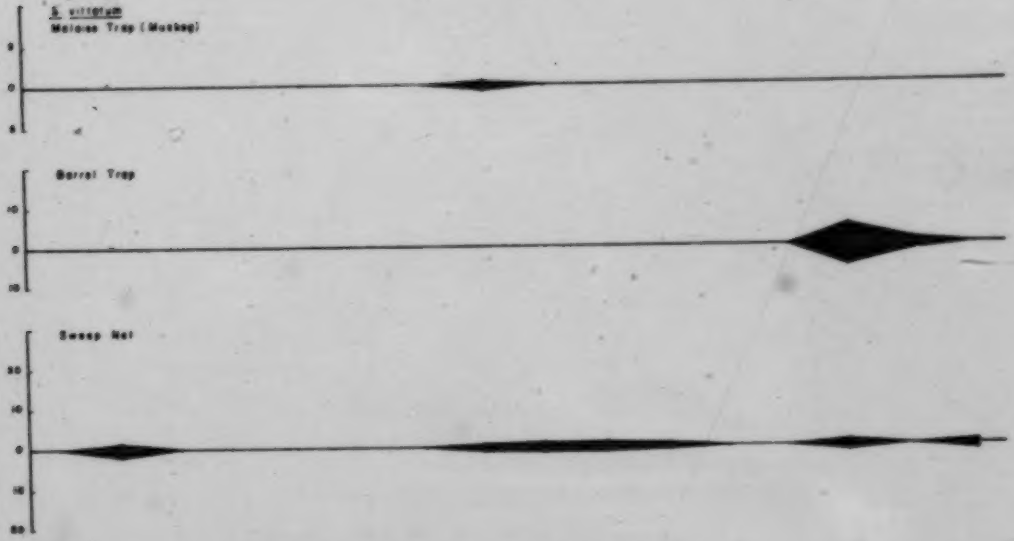


Figure 27

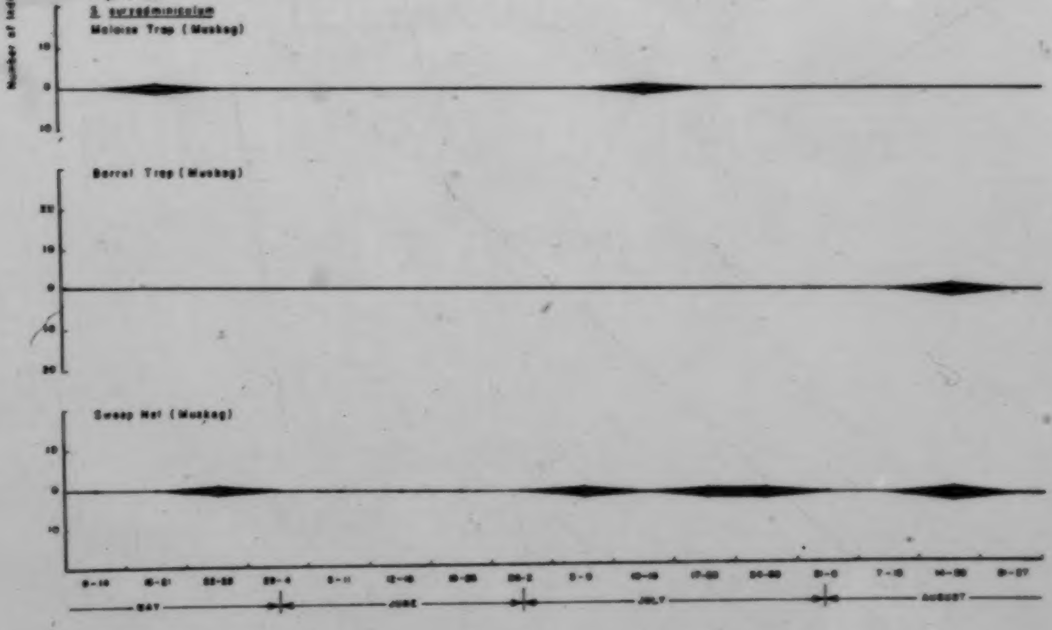


Figure 28

ADULT BLACK FLY ACTIVITY
1976

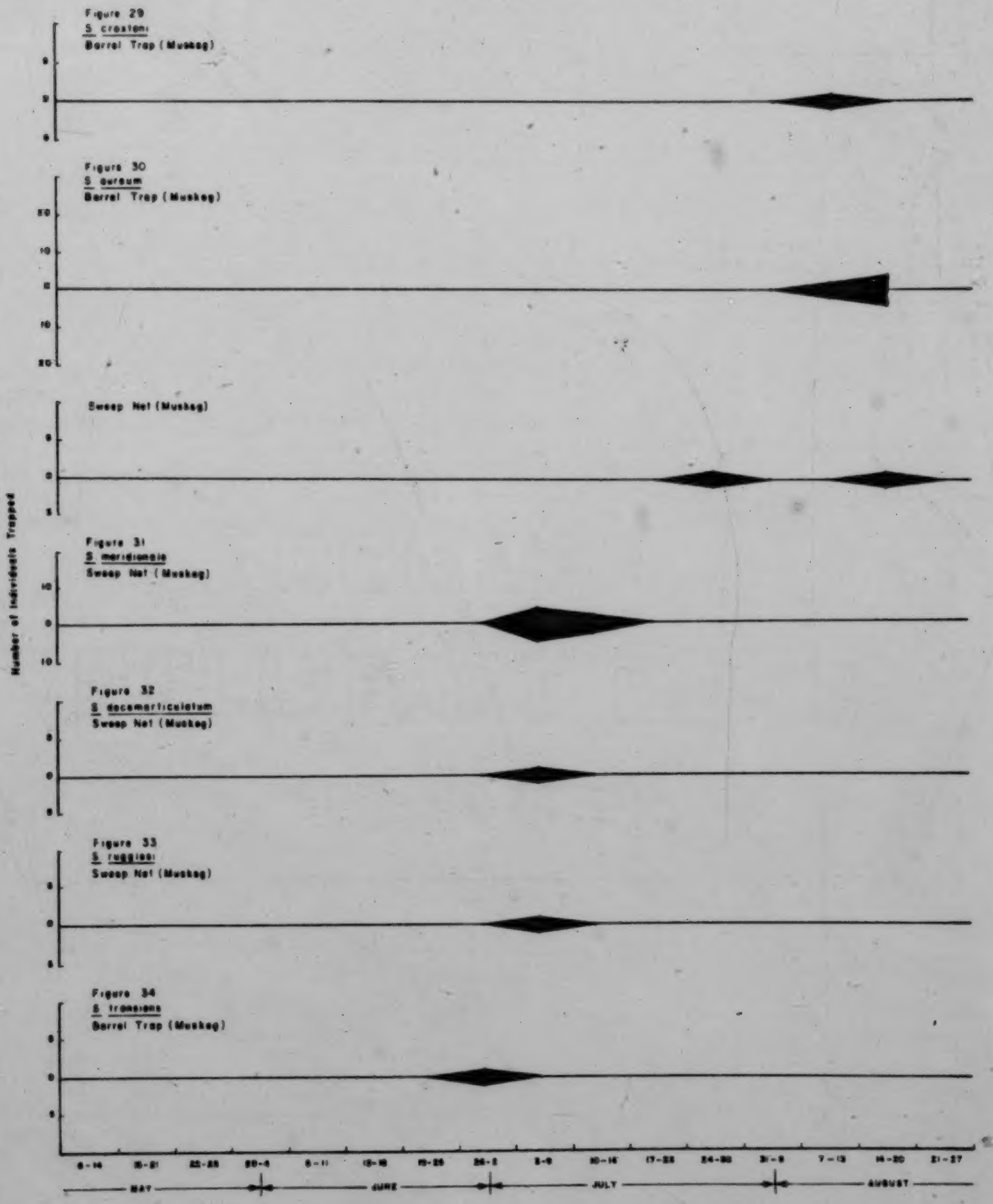


Figure 29
S. croxtoni
Barrel Trap (Muskeg)

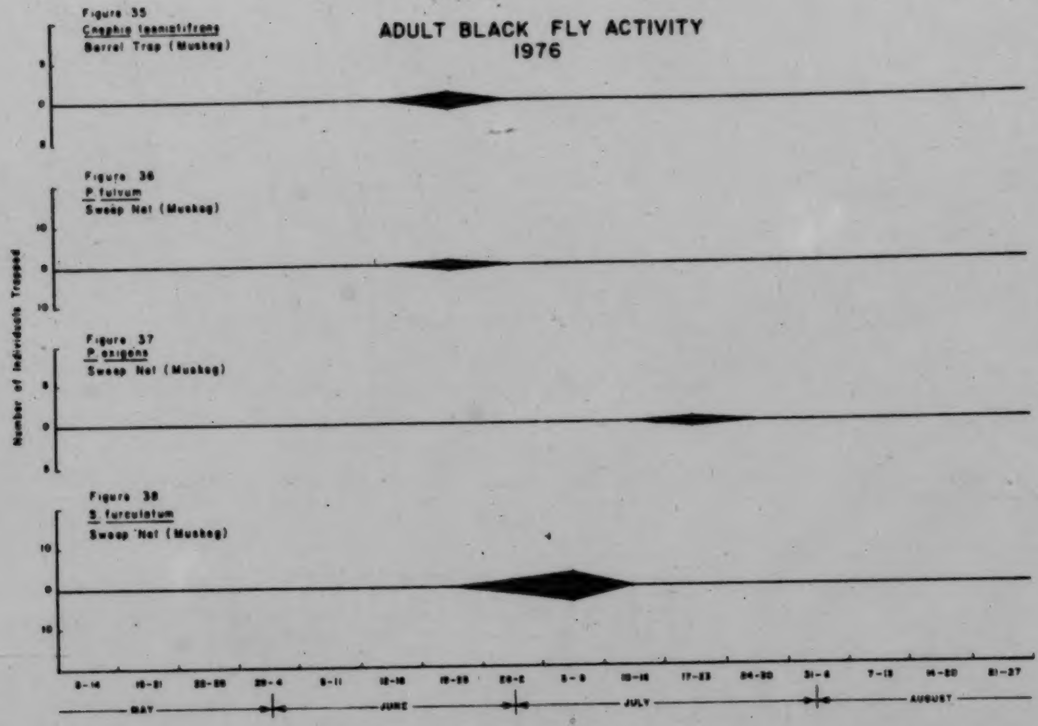
Figure 30
S. aureum
Barrel Trap (Muskeg)
Sweep Net (Muskeg)

Figure 31
S. meridionale
Sweep Net (Muskeg)

Figure 32
S. decemarticulatum
Sweep Net (Muskeg)

Figure 33
S. rugglesi
Sweep Net (Muskeg)

Figure 34
S. transiens
Barrel Trap (Muskeg)



ADULT BLACK FLY ACTIVITY
1976

Figure 35
Cnephia taeniatifrons
Barrel Trap (Muskeg)

Figure 36
P. fulvum
Sweep Net (Muskeg)

Figure 37
P. exigens
Sweep Net (Muskeg)

Figure 38
S. furculatum
Sweep Net (Muskeg)

ADULT BLACK FLY ACTIVITY
1976

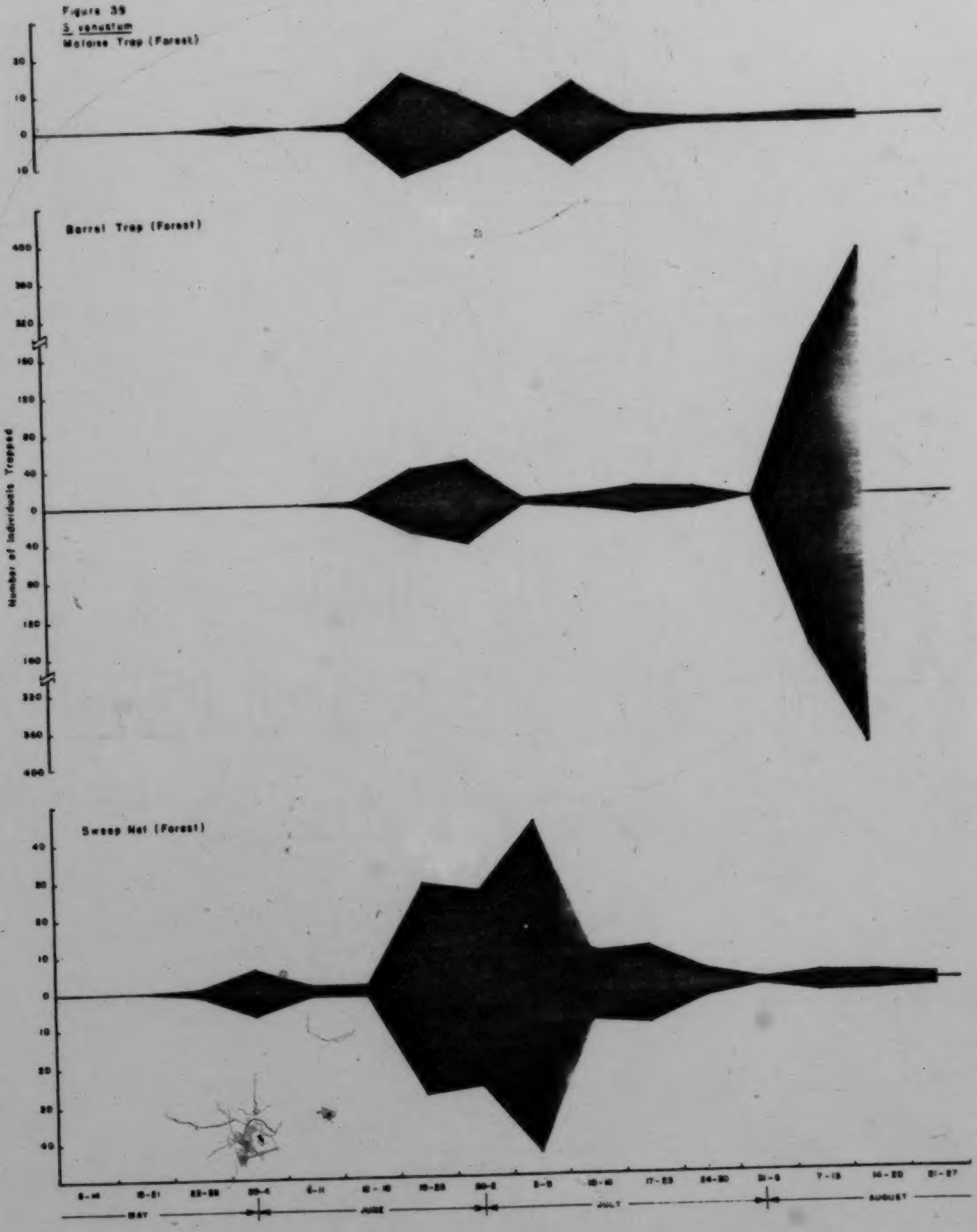


Figure 35
S. venustum

ADULT BLACK FLY ACTIVITY
1976

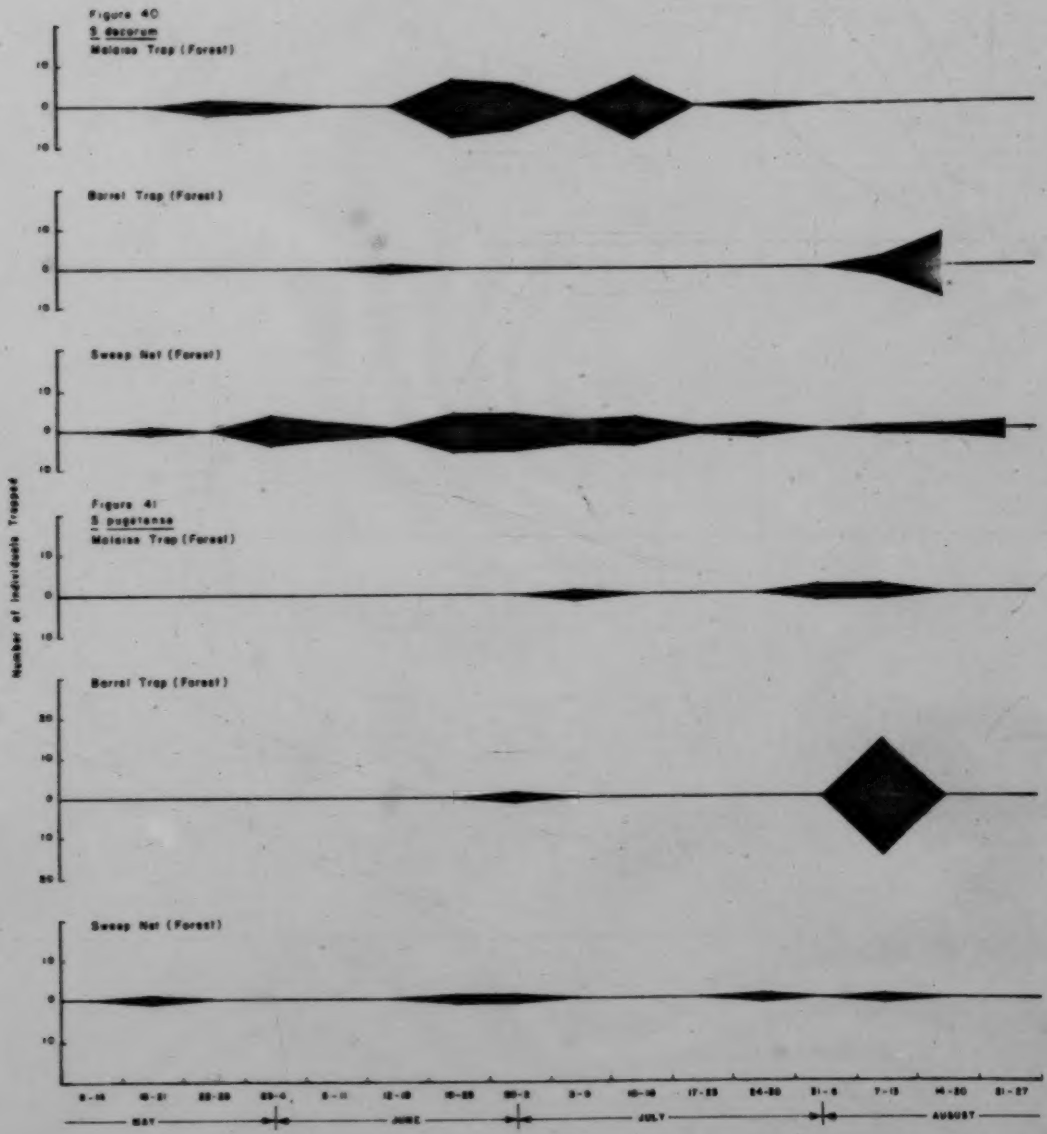


Figure 40
S decorum

Figure 41
S pugetense

ADULT BLACK FLY ACTIVITY
1976

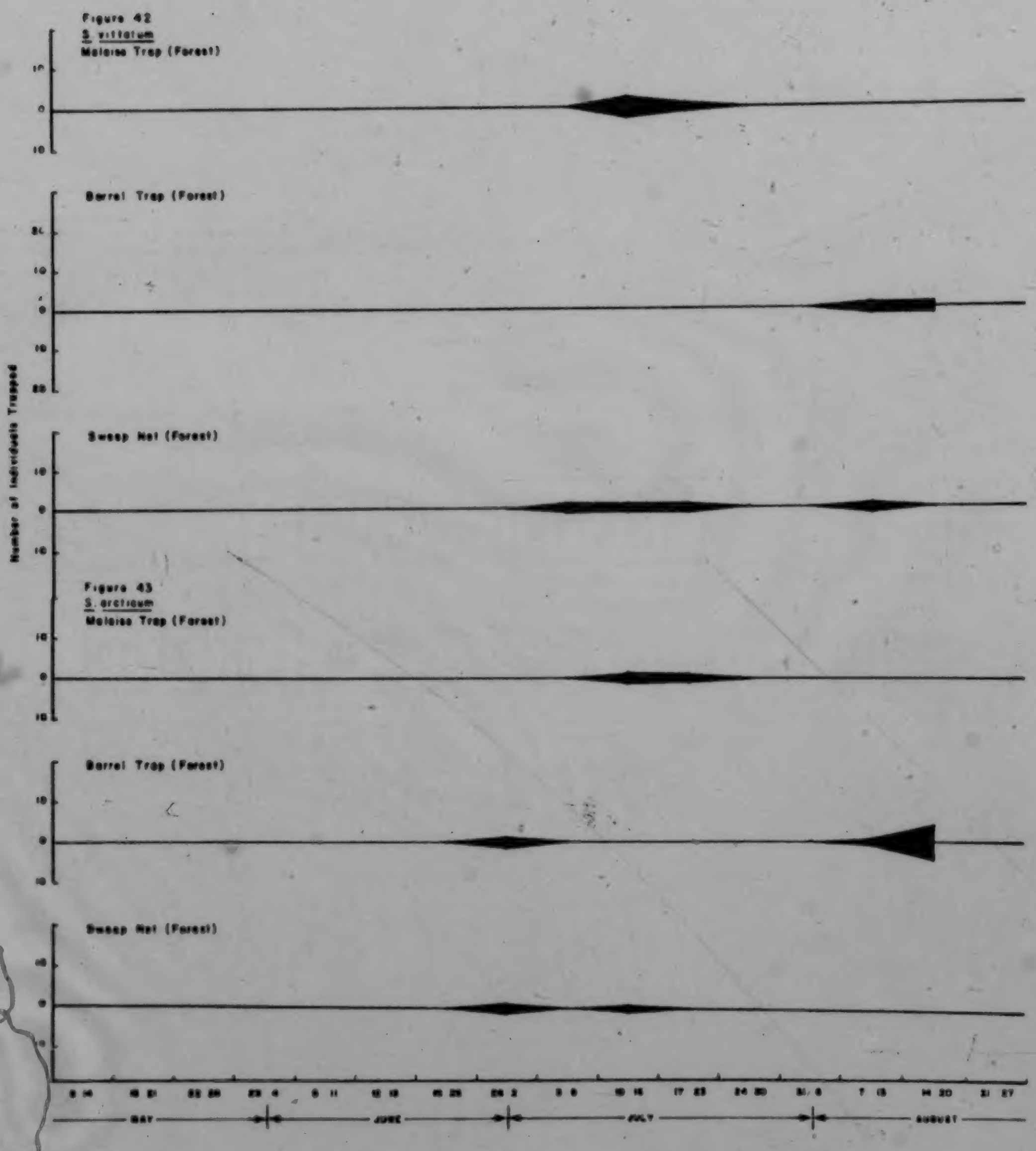
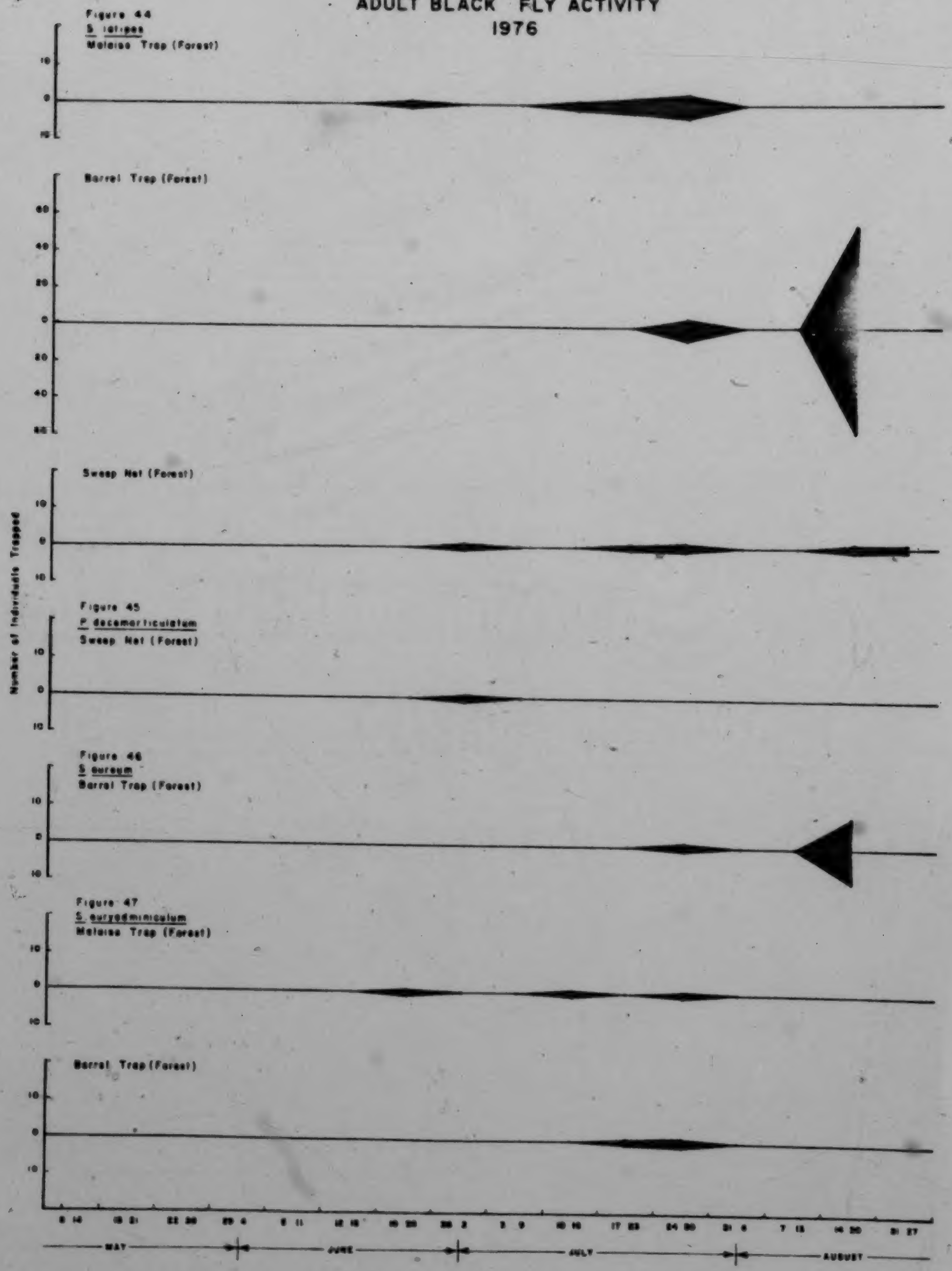


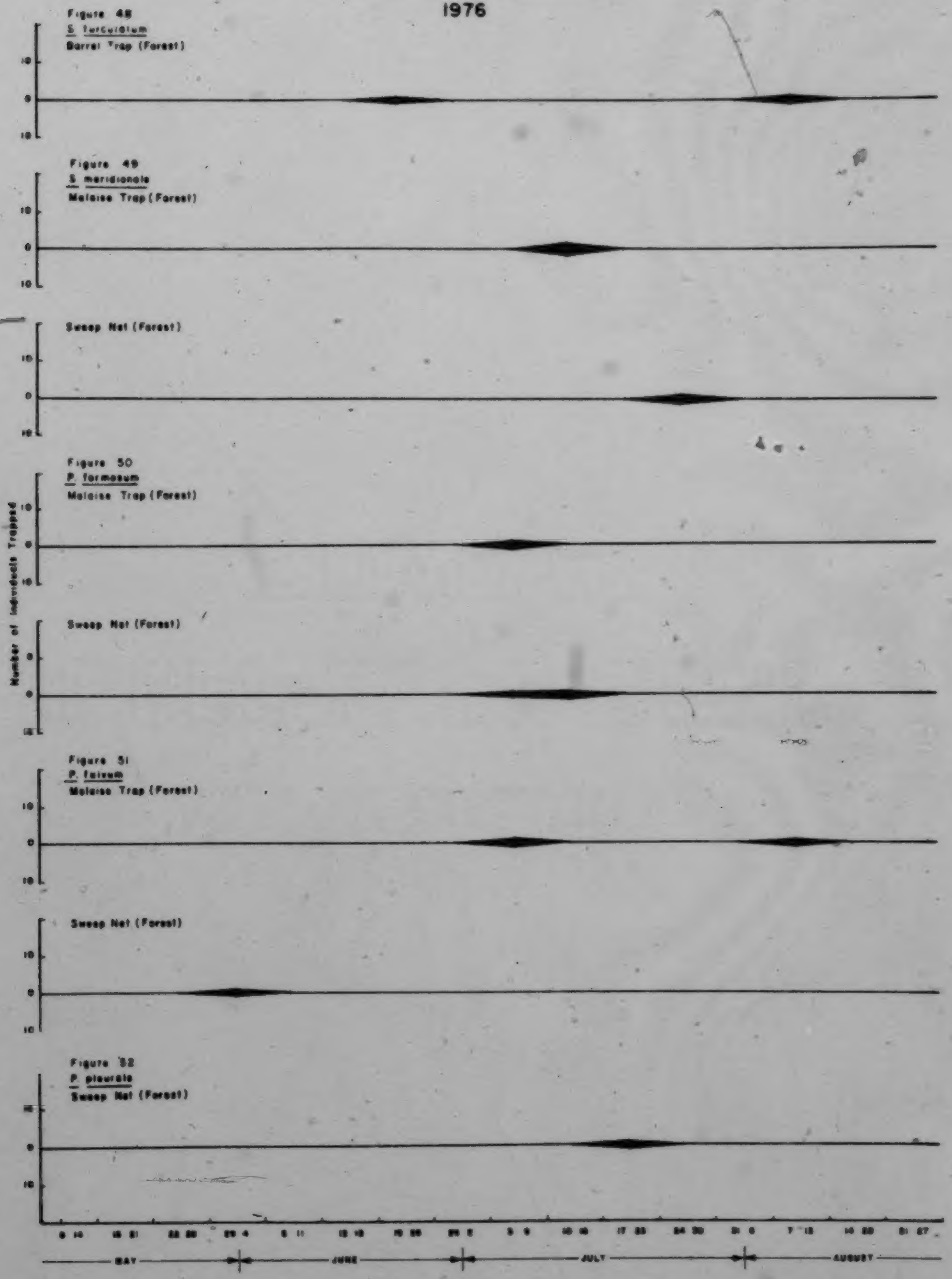
Figure 42
S. vittatum

Figure 43
S. arcticum

ADULT BLACK FLY ACTIVITY
1976



ADULT BLACK FLY ACTIVITY
1976



The seasonal activities for the adult black fly species varied depending on species with *S. venustum* (Figures 22 and 39), *S. decorum* (Figures 23 and 40) and *Simulium vittatum* Zetterstedt (Figures 27 and 42) being active throughout the 1976 field season (May 15 to August 27). *Simulium arcticum* (Figures 25 and 43), *S. latipes* (Figures 26 and 44) and *S. furculatum* (Figures 38 and 48) first occurred in late spring (June 19) and were present for the remainder of the field season, while *Simulium croxtoni* Nickolson and Mickel (Figure 29) and *Simulium aureum* Fries occurred first in mid-summer.

Three peak activity periods were recorded for both *S. venustum* (May 29-June 4, June 19-25 and July 3-23) (Figures 22 and 39), and *S. decorum* (May 29-June 4, June 19-July 2, and July 17-23) (Figures 23 and 40) indicating they are multivoltine species. *Simulium arcticum* (Figures 25 and 43), *S. latipes* (Figures 26 and 44), *S. vittatum* (Figures 27 and 42) *S. aureum* (Figures 30 and 46) and *Prosimulium decemarticulatum* (Twinn) (Figures 32 and 45) showed similar seasonal adult activity. Univoltine species included *S. meridionale* (Figures 31 and 49), *Prosimulium formosum* Shewell (Figure 50) and *Prosimulium fulvum* (Figures 36 and 51).

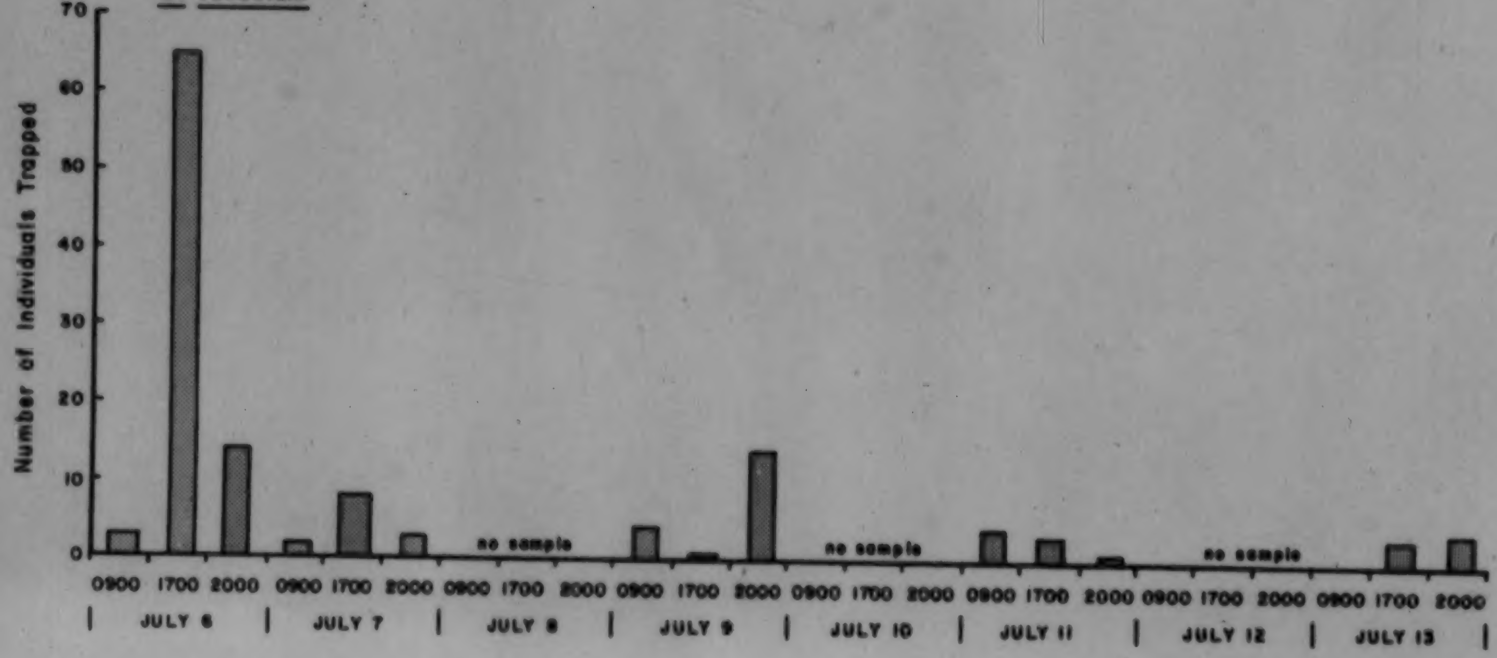
Diel activities were not clear, although *S. venustum* (Figure 53) was more active in the late afternoon and early evening.

The most effective adult black fly trapping method in terms of the number of species trapped was sweep netting which trapped adults of 17 blackfly species of which *P. decemarticulatum* (Figure 32), *Simulium rugglesi* Nickolson and Mickel (Figure 33), *Prosimulium exigens* Dyar and Shannon (Figure 37) and *Prosimulium pleurale* Malloch (Figure 52) were trapped only by sweep netting. The carbon dioxide baited barrel trap

DIEL ACTIVITY IN MUSKEG COMMUNITY FROM JULY 6 - 13, 1976

Figure 53

S. venustum



was second in trapping effectiveness, trapping adults of 13 black fly species, of which *S. croxtoni* (Figure 29), *Simulium transiens* Rubzov (Figure 34) and *Cnephia taeniatifrons* (Enderlein) (Figure 35) were trapped only by this method. Adults of 10 blackfly species were collected using the modified malaise trap. In terms of the number of individual adult black flies collected the carbon dioxide baited barrel trap was apparently more efficient. However, the longer sampling period (12 hours) compared to the shorter sampling period for the modified malaise trap (2 hours) and the sweep net (20 sweeps) could well account for the larger number of individuals taken in the barrel trap. In general there was agreement in adult black fly activity peaks between the three trapping methods, with close agreement between the modified malaise trap and the insect sweep netting.

VIII. BLACK FLY ADULTS ATTRACTED TO AND BLOOD FEEDING ON MOOSE

A. Materials and Methods

Adults of black fly species attracted to and blood feeding on moose were collected from thirteen wild trapped moose and a penned moose as bait. Observations were made on preferred feeding sites on the host and the host's response to biting fly activity. Wild moose were live trapped and immobilized (see page 26). These moose were swept for black flies using an insect sweep net immediately upon approaching the moose and again just prior to administering the antidote (M50-50 diprenorphine) to the tranquilizing drug. I was the second person to the downed moose and took the initial sweep sample before examination of the moose by the wildlife biologists. Because of the difficulties of that work, the number of sweeps was not standardized.

Individual blood engorging blackflies were picked from downed moose with forceps and a paint brush moistened in alcohol. Each sample was stored in a labelled vial with 70% ethanol. Information recorded included moose identification number, trap number, sampling method, time and date, moose age and sex, and local weather conditions.

In 1976 two orphaned female moose calves (approximately 6 weeks old) were obtained by Dr. W.M. Samuel, University of Alberta, through the Alberta Fish and Wildlife Division. On June 6 a grizzly bear entered the moose pen and killed the first moose calf, but a second moose calf was taken to the study site on June 16, 1976. This moose was used to facilitate regular sampling of black fly adults attracted to and feeding on it during both seasons. Two sampling methods were used, insect sweep netting and a fly trap baited with the moose. A sweep net sample consisted of twenty sweeps over and around the length of the standing moose. A regular sampling schedule was maintained on alternate days at 0900, 1700 and 2000 hours in 1976. In 1977 samples were taken every third day at 0900, 1700 and 2000 hours. The contents of the net sample were sprayed with insecticide (Black Flag House and Garden Insect Killer®) and stored in alcohol.

The moose baited fly trap was a rectangular enclosure constructed of plywood and insect screening (Hudson, 1977). A one-way fly entrance ran the length of the trap on either side. The trap was cleared of flies immediately prior to taking a sample. The moose was led into the trap by way of an entrance door and the trap closed. A sample consisted of flies trapped in a one-hour period. A regular sampling schedule was maintained at 0900, 1700 and 2000 hours, except during heavy rains, or in 1977 when only one person was in camp. The latter exception was a safety precaution, as the moose required two people for handling. After removing the moose from the trap, black flies were collected and stored in alcohol.

Four times during the summer in 1977, control samples with the fly trap not baited were taken to evaluate the attractiveness of the trap per se. These controls followed the same schedule as for the baited samples, but were on the day preceding or following a regular baited sample. Such was done to minimize any effect of lasting moose odour acting as an attractant.

B. Results

1. Response to Biting Flies

Both trapped wild moose and the penned moose responded to high fly activity. Field conditions unfortunately did not permit isolation of behavioural responses of moose to black flies in particular, so observations here are a summation of all biting fly activity. The penned moose calf, prior to losing its natal hair in late July (1976), seemed less affected than older moose by biting fly activity. The long, dense natal hair covered the entire body surface except the nose and deep recessions of the inner ear where hair was short. The moose calf used ear twitching, head and body shaking and scratching in an apparent effort to dislodge flies. On occasions it was observed to race erratically around the pen until exhausted, then lie down. Most commonly, it would lie under low shrubs or in the lean-to shelter constructed to offer some protection from adverse weather.

During peak biting fly activity, wild-trapped moose and the penned yearling moose moved around constantly, frequently twitching the ears and rubbing the hind legs together in a quick jerking motion. Muscle spasms in the form of quivering along the body core and the legs were also observed.

2. Black Fly Feeding Sites on Moose

Observations clearly showed black flies concentrated their probing and feeding activity in the less dense and short haired areas on the moose. The heaviest black fly activity was on the legs, in particular the inner and outer aspect from the hoof to about 10 centimeters above the tibio-tarsal joints. The belly, brisket and anal area were also sites of black fly biting activities. Few black flies

ADULT BLACK FLY ACTIVITY AT MOOSE BAITED FLY TRAP - 1976

Figure 54

S. decorum

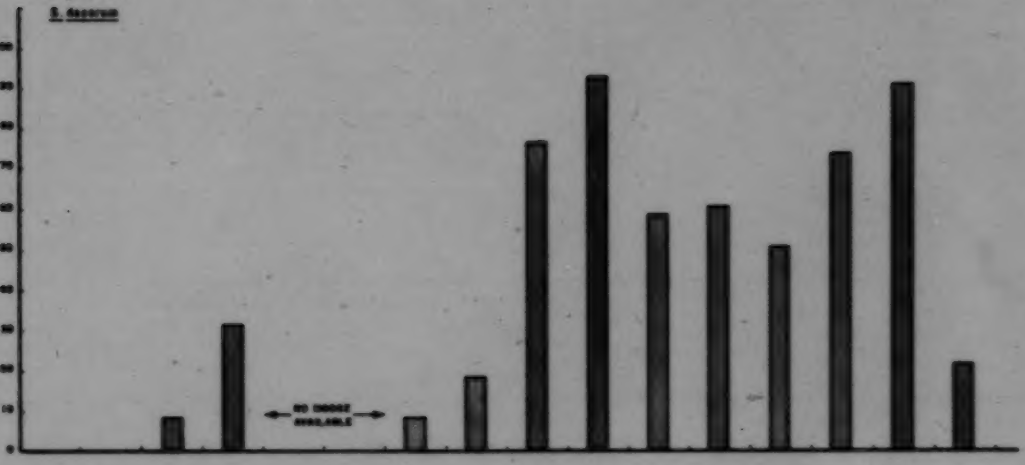
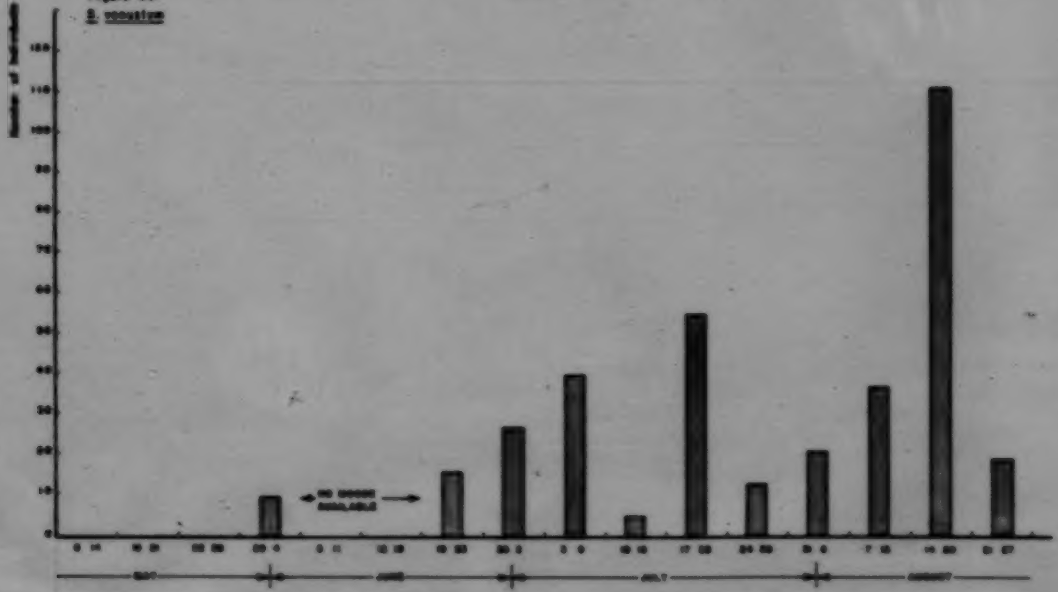
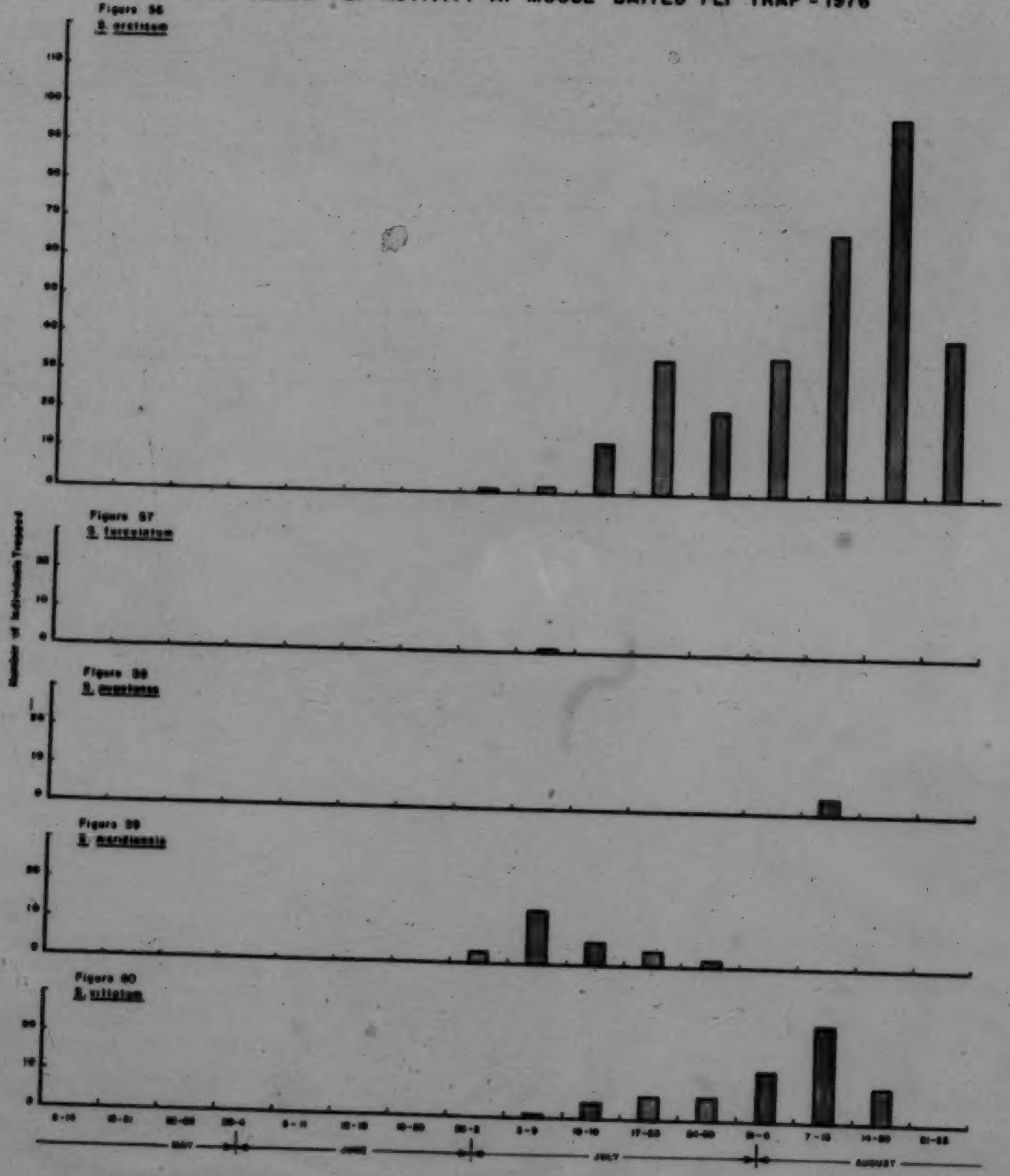


Figure 55

S. venustum



ADULT BLACK FLY ACTIVITY AT MOOSE BAITED FLY TRAP - 1976



ADULT BLACK FLY ACTIVITY AT MOOSE BAITED FLY TRAP - 1976

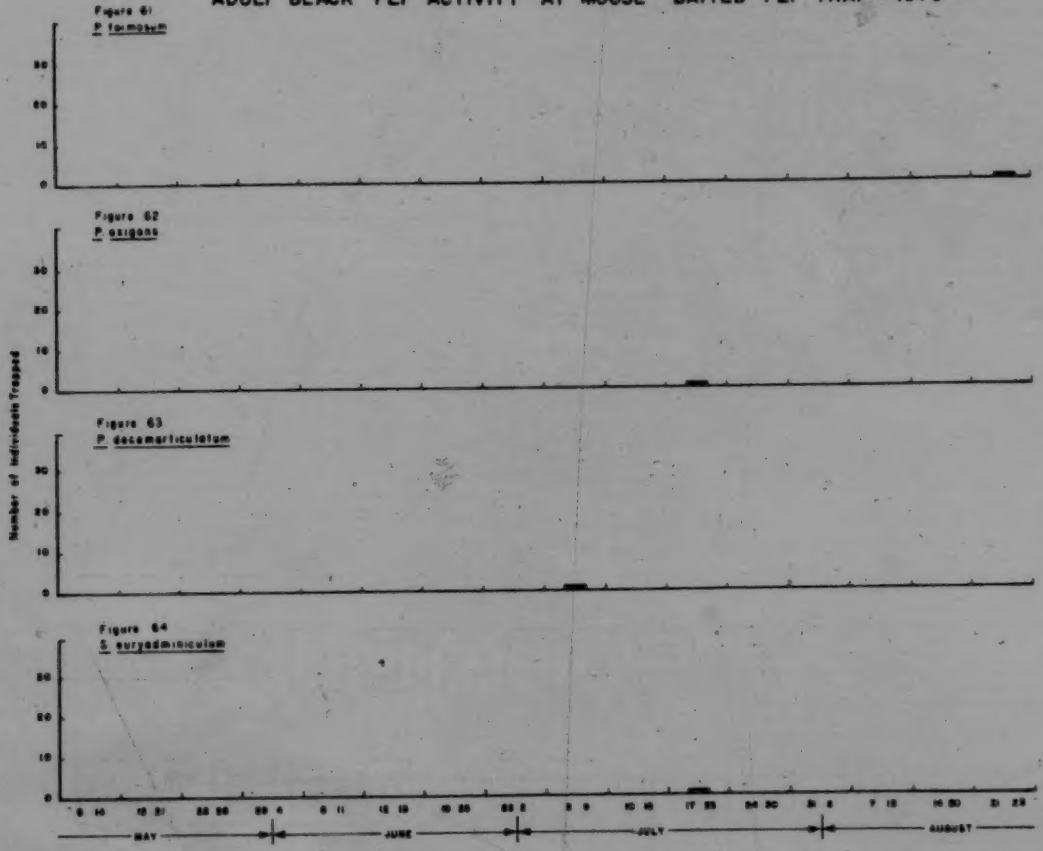


Figure 61
P. formosum

Figure 62
P. exigens

Figure 63
P. decemarticulatum

Figure 64
S. euryadminiculum

were observed on the head and ears. A hairless callused area with small lesions on the hind legs just distal to the tibio-tarsal joints was a preferred site for Lyperosiops sp., possibly L. alcis (Muscidae, Diptera), but occasionally used by adult black flies.

3. Black Flies Attracted to Moose

Adults of fifteen black fly species were attracted to moose (Table XI). In 1976 adults of a total of eleven black fly species were collected from the moose baited fly trap and insect sweep net; S. decorum (Figures 54 and 68), S. venustum (Figures 55 and 69), S. arcticum (Figures 56 and 67), S. vittatum (Figures 60 and 66) and S. meridionale (Figure 59) were the most abundant (Figures 54-69). Of these species, adults of S. decorum (Figures 54 and 68) and S. venustum (Figures 55 and 69) were most abundant during late June and July. Both trapping methods showed similar trends in black fly abundance, however, the moose baited fly trap trapped six black fly species additional to those taken in the insect sweep net (Table XI). With the exception of those of S. meridionale (Figure 59), adults of these six species were taken in low numbers. The disturbance created while sweep netting around the moose and the short sampling period may have adversely influenced trapping some of these less abundant black fly species. Simulium furculatum (Figure 57) and S. pugetense (Figure 58) were collected only from the moose baited fly trap and only in 1976 when the penned moose was a calf. In 1977 the numbers of black fly adults attracted to moose were higher. Weather conditions that may have influenced this greater abundance of black flies, included, high precipitation in the summer of 1976 and a mild winter with above normal snowfall.

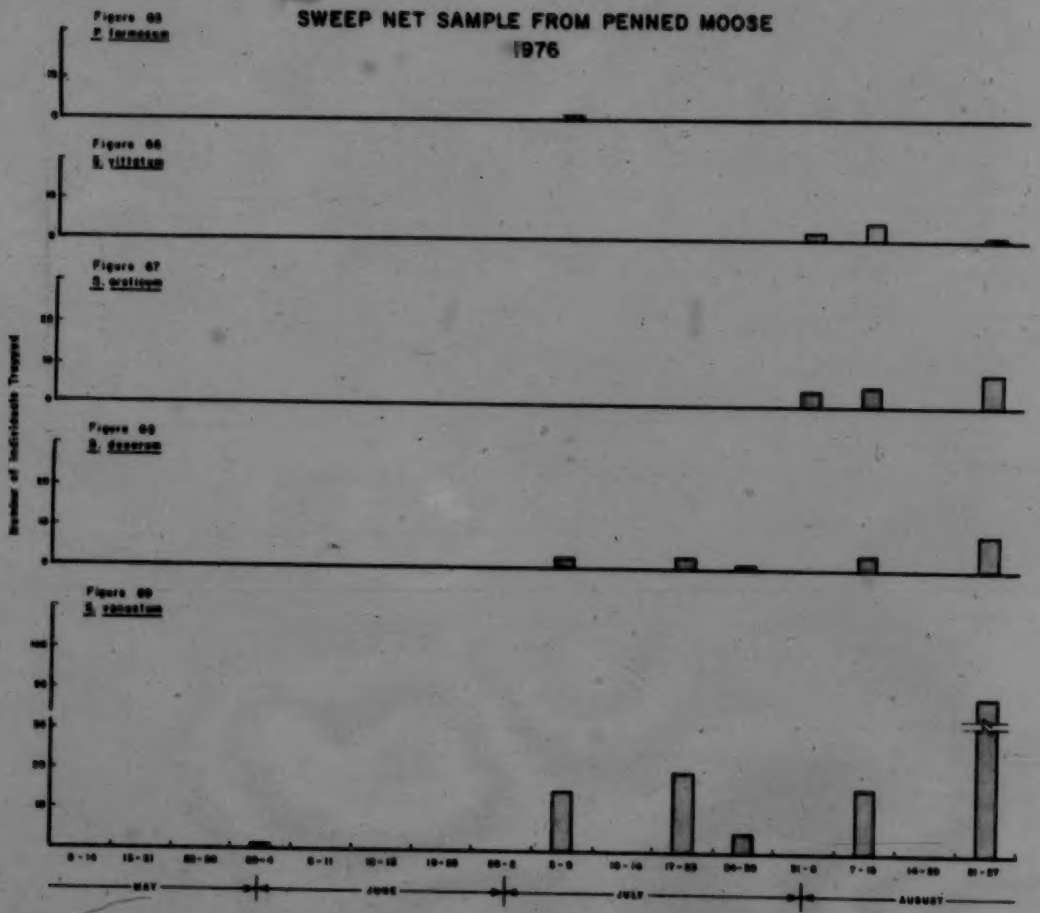
TABLE XI

ADULTS OF BLACK FLY SPECIES ATTRACTED TO MOOSE IN THE SWAN HILLS

	Wild Moose 1976		Penned Moose (#3)			
			1976 (calf)		1977 (yearling)	
Species	Sweep Net	Hand Picked	Sweep Net	Fly Trap	Sweep Net	Fly Trap
S. arcticum	+	+	+	+	+	+
S. decorum	+	+	+	+	+	+
S. venustum	+	+	+	+	+	+
S. vittatum	+	+	+	+	+	+
S. meridionale	+	-	-	+	-	+
S. furculatum	-	-	-	+	-	-
S. euryadminiculum	-	-	-	+	+	+
S. pugetense	-	-	-	+	-	-
S. aureum	-	-	-	-	+	+
S. latipes	-	-	-	-	-	+
S. croxtoni	-	-	-	-	-	+
S. jenningsi	+	-	-	-	-	-
P. formosum	-	-	+	+	+	+
P. decemarticulatum	-	-	-	+	+	+
P. exigens	-	-	-	+	-	+

(- = not present)

SWEEP NET SAMPLE FROM PENNED MOOSE
1976



In 1977 when the penned moose was a yearling, adults of 13 black fly species were collected from the moose baited fly trap (Table XI). The most abundant species were: *S. decorum* (Figure 70), *S. venustum* (Figure 71), *S. arcticum* (Figure 72), *S. vittatum* (Figure 73) and *S. aureum* (Figure 74). Of these, adults of *S. decorum*, *S. venustum*, *S. arcticum* and *S. vittatum* were abundant in June and July (Figures 70 and 73). *Simulium aureum* (Figure 74), *S. croxtoni* (Figure 75) and *S. latipes* (Figure 76) were not collected from the penned moose calf in 1976 (Table XI). Adults of eight black fly species were collected in the insect sweep net (Figures 72-79) and these showed similar trends in seasonal abundance as was noted from the moose baited fly trap. In 1977 the first adult black flies were collected one week earlier (May 8) than in 1976.

Adult black fly species collected in the non-baited fly trap are compared with those taken in the moose baited fly trap in Figures 90 to 100. The non-baited fly trap collected the same species as the moose-baited fly trap, except *P. formosum*, *S. euryadminiculum* and *S. croxtoni* which came only to the baited trap (Figures 97, 99 and 100). The number of female black flies collected in the non-baited fly trap was less than in the moose-baited fly trap. Adults of six black fly species were collected from immobilized wild moose in 1976 (Table XI). The same black fly species were collected from the penned moose in 1976, with the exception of *Simulium jenningsi* Peterson which was collected in the sweep net on July 16 at 1400 hours. This is the first known record of *S. jenningsi* in Alberta and identification is based on one female.

Of the fifteen adult black fly species attracted to moose, only

ADULT BLACK FLY ACTIVITY AT MOOSE BAITED FLY TRAP - 1977

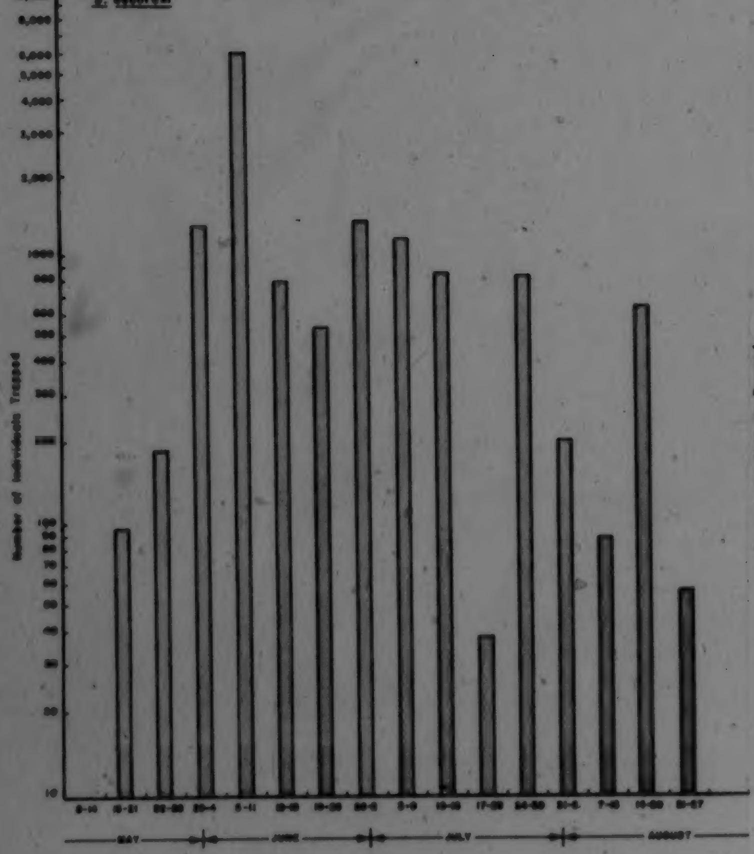


Figure 70
S. decorum

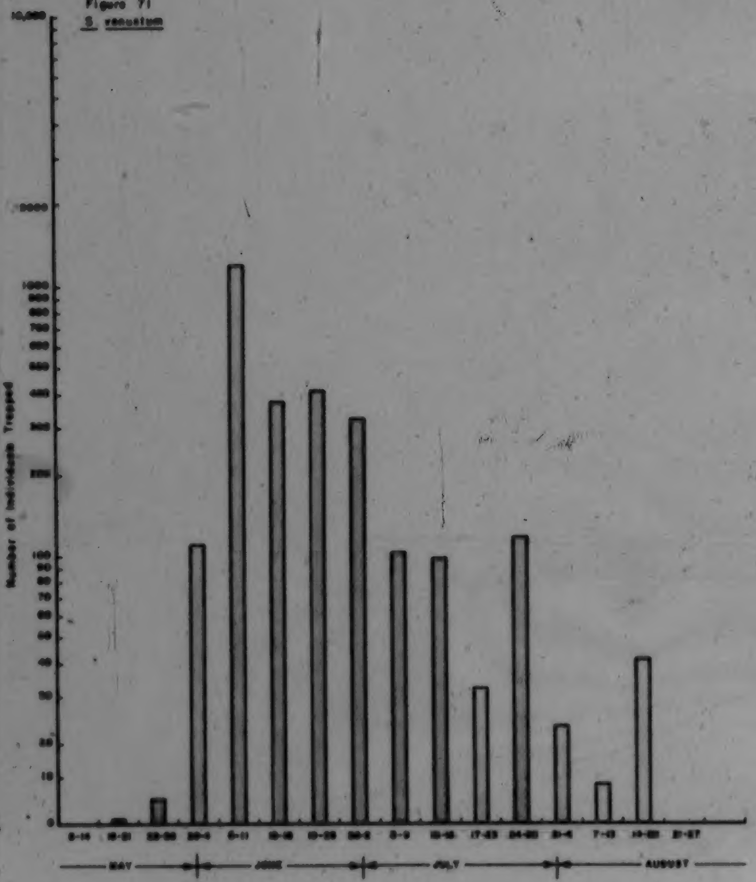


Figure 71
S. venustum

ADULT BLACK FLY ACTIVITY AT MOOSE BAITED FLY TRAP - 1977

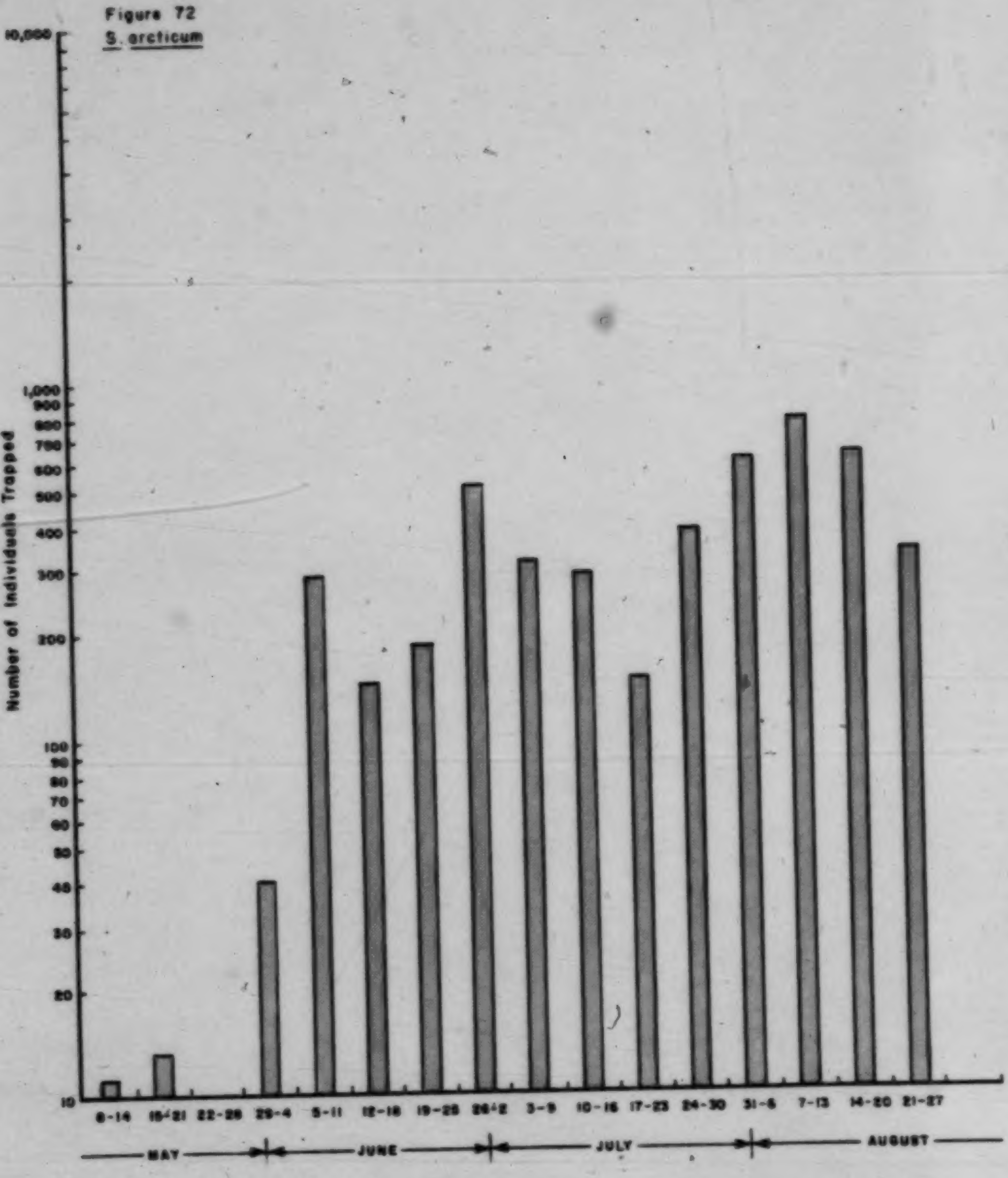


Figure 72

S. arcticum

ADULT BLACK FLY ACTIVITY AT MOOSE BAITED FLY TRAP - 1977

Figure 73

S. vittatum

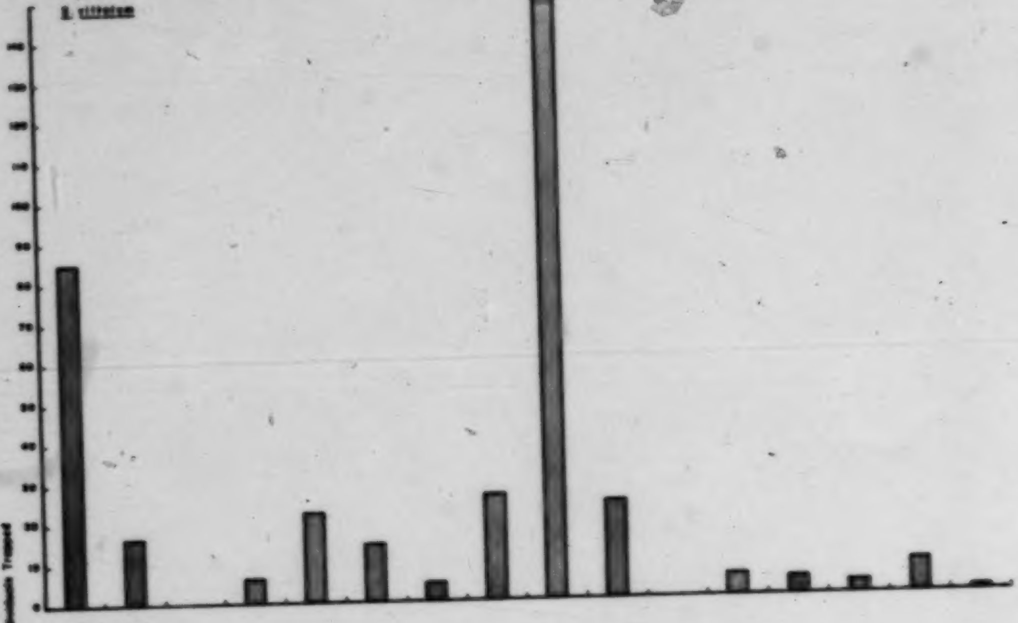
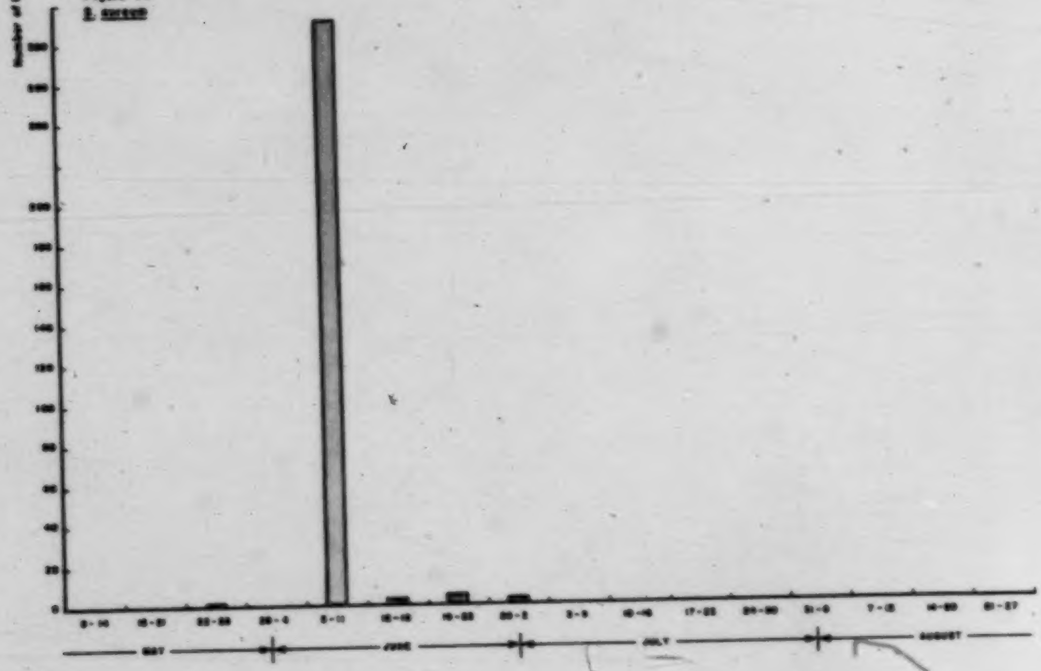
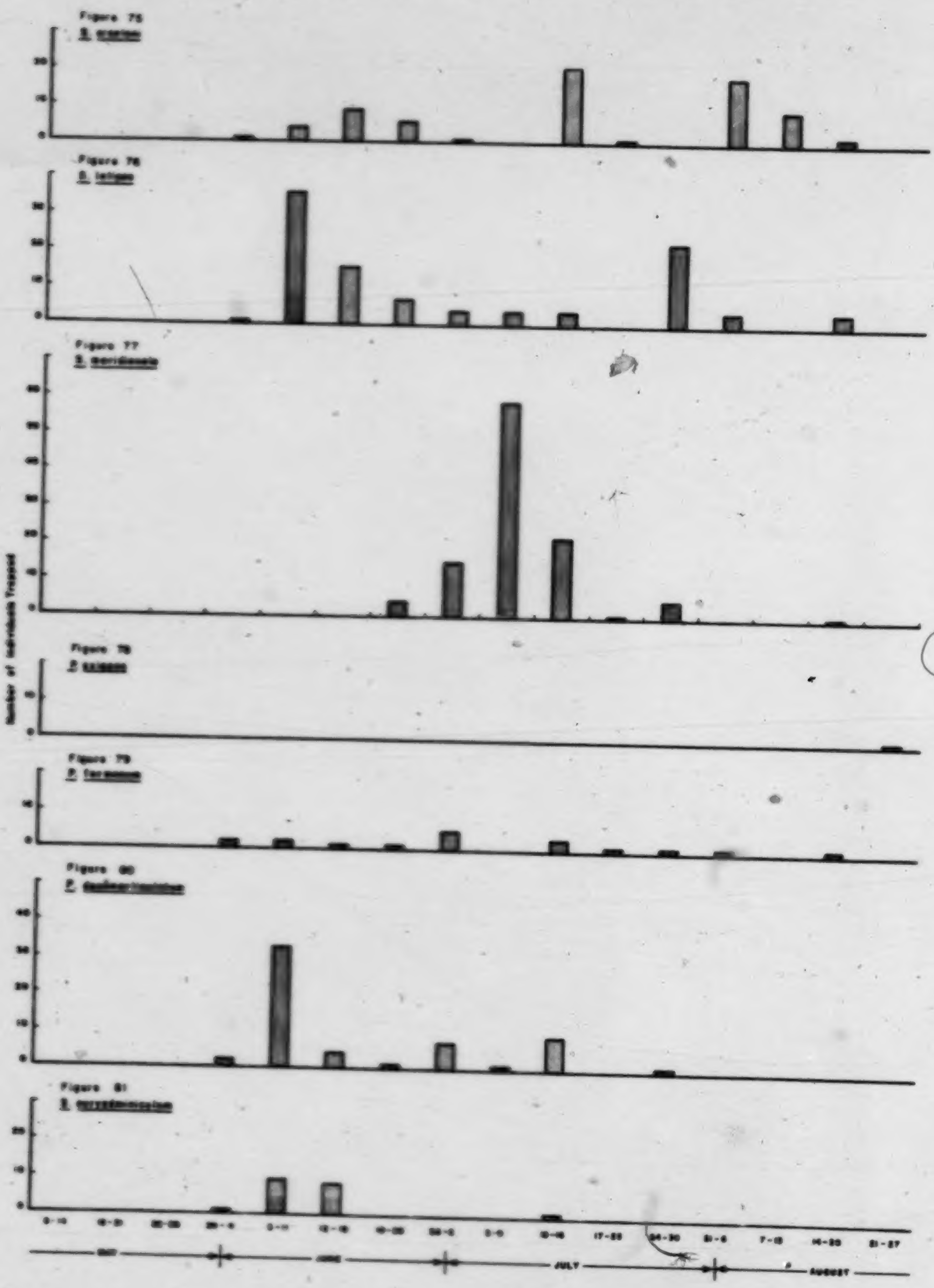


Figure 74

S. aureum



ADULT BLACK FLY ACTIVITY AT MOOSE BAITED FLY TRAP - 1977



SWEEP NET SAMPLE FROM PENNED MOOSE
1977

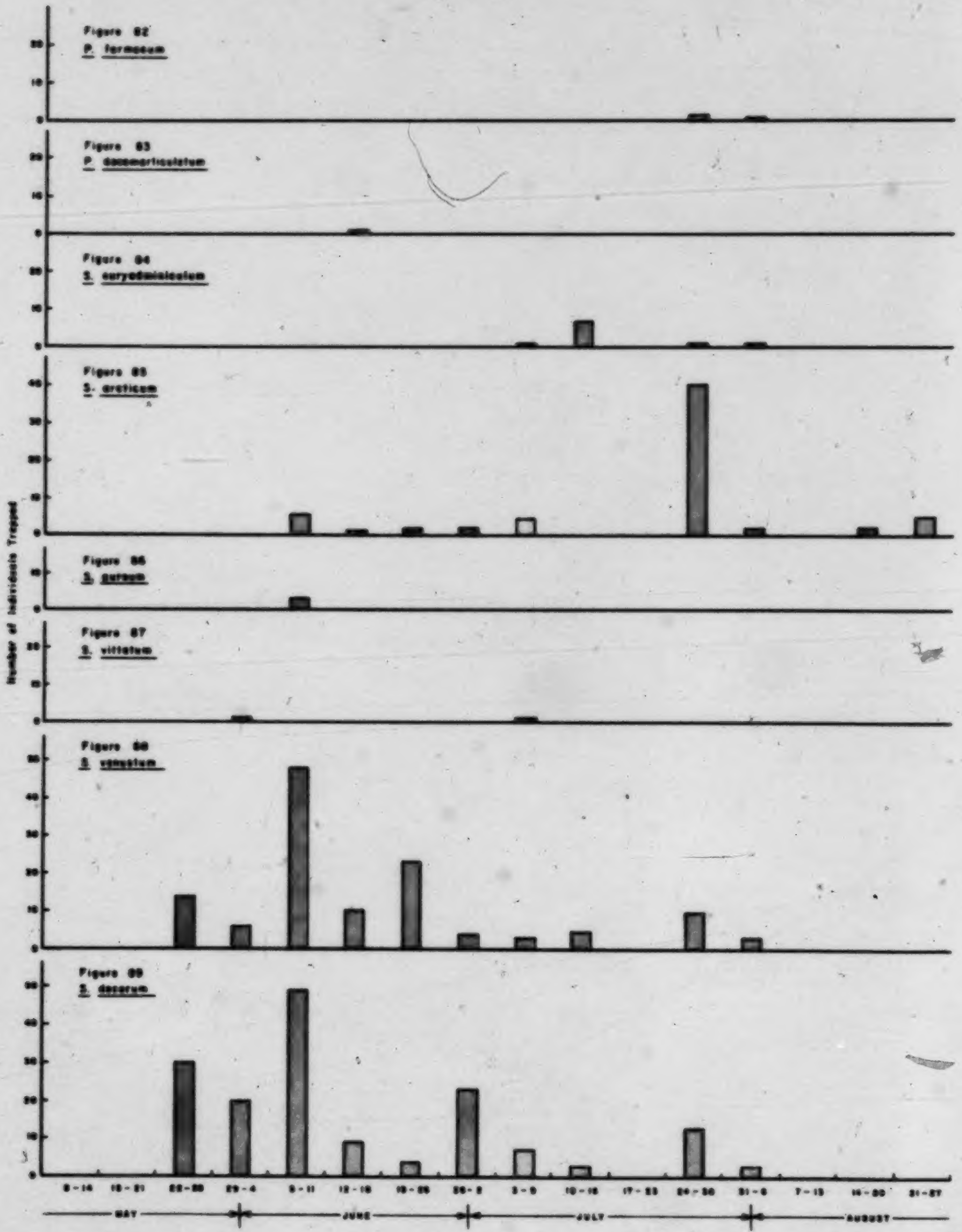


Figure 82 *P. formosum*

Figure 83 *P. decemarticulatum*

Figure 84 *S. euryadminiculum*

Figure 85 *S. arcticum*

Figure 86 *S. aureum*

Figure 87 *S. vittatum*

Figure 88 *S. venustum*

Figure 89 *S. decorum*

COMPARISON OF MOOSE BAITED AND NON BAITED FLY TRAP 1977

Figure 90

S. decorum

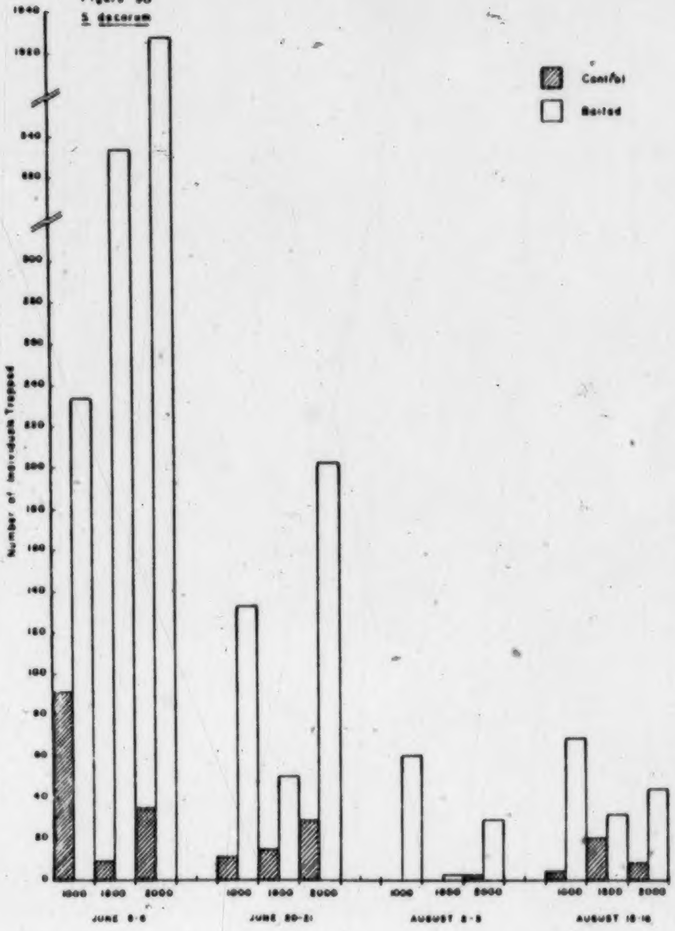


Figure 91

S. arcticum

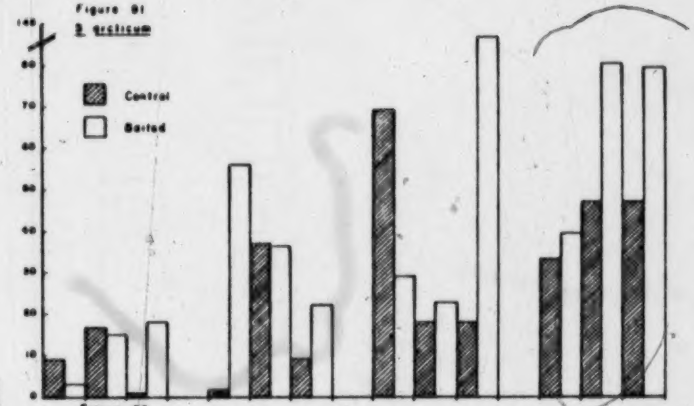
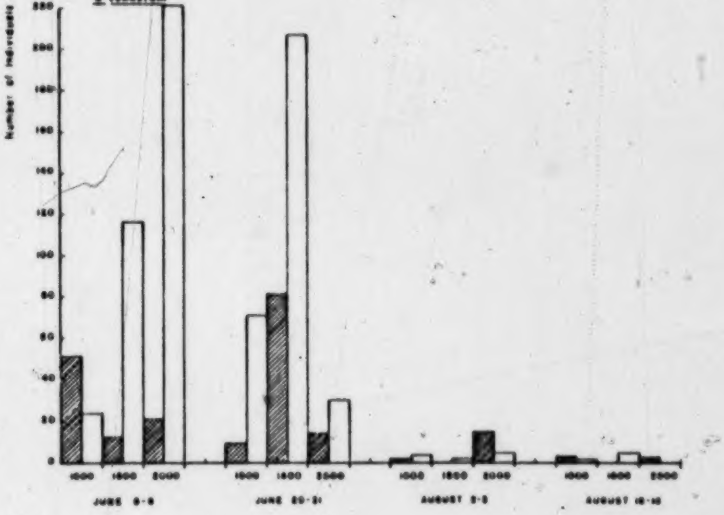


Figure 92

S. venustum



COMPARISON OF MOOSE BAITED AND NON BAITED FLY TRAP 1977

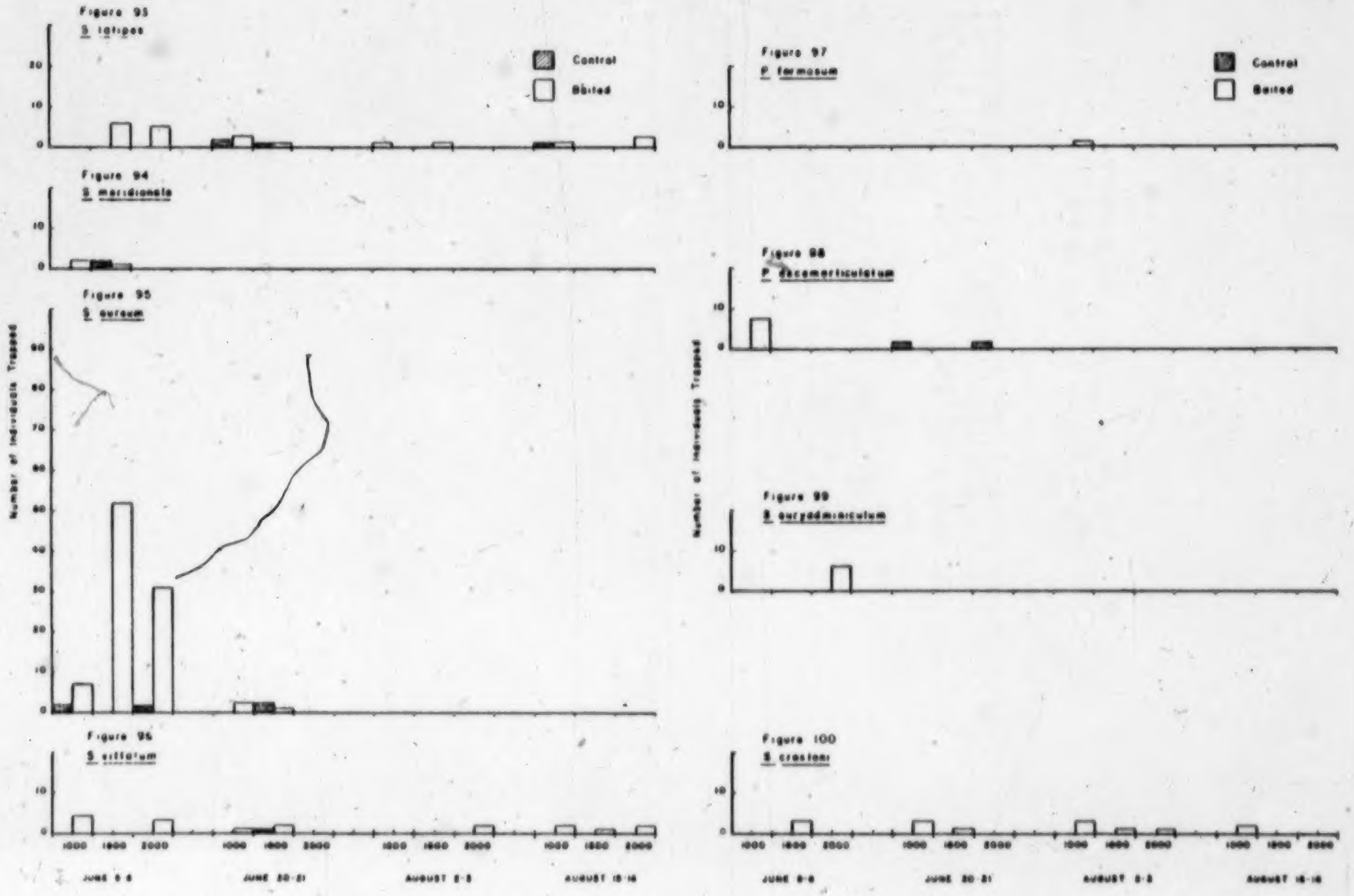


Figure 93
S latipes

Figure 94
S meridionale

Figure 95
S aureum

Figure 96
S vittatum

Figure 97
P formosum

Figure 98
P decemarticulatum

Figure 99
S euryadminiculum

Figure 100
S croxtoni

S. arcticum, S. aureum, S. decorum, S. venustum, S. vittatum and P. formosum were found to feed on the blood of moose. Simulium arcticum, S. decorum and S. venustum blood fed on the penned moose in both 1976 and 1977, while S. vittatum and P. formosum though collected both seasons from the penned moose (Table XI) only blood fed from the moose yearling in 1977 (Table XII). Simulium aureum was collected from moose only in 1977.

TABLE XII

PERCENT OF BLACK FLIES BLOOD ENGORGED FROM PENNED MOOSE 1976-1977

Species	Number Trapped	Number Blood Engorged	% Blood Engorged
1976			
S. arcticum	333	1	0.3
S. decorum	648	3	0.5
S. venustum	355	20	5.6
S. vittatum	59	0	0.0
1977			
S. arcticum	5,628	39	0.7
S. aureum	327	3	0.9
S. decorum	14,879	127	0.9
S. venustum	3,434	211	6.1
S. vittatum	533	36	6.7
P. formosum	28	15	53.6

IX. DETERMINATION OF VECTORS

A. Materials and Methods

Three hundred and sixty-four (364) blood engorged female black flies collected from wild trapped and penned moose were dissected and the gut contents examined for microfilariae. To do this the black flies were identified, then placed in hot 2% potassium hydroxide solution for 10-15 minutes to liquefy the blood meal. They were then mounted on a microscope slide, viewed with dissecting microscope (Wild M5) and the abdomen of the fly separated from the thorax using a scalpel and needle point forceps. The intact blood meal was removed by applying gentle pressure with forceps to the abdomen behind the blood meal and moving the forceps anteriorly. A cover slip was placed over the blood meal and squeezed to form a thin-layer blood-squash. This was examined for microfilariae under a binocular compound microscope (Zeiss) at 100 magnification.

B. Results

Of the six black fly species that blood fed on the penned moose, only S. venustum and S. decorum adults contained microfilariae in their blood meal (Table XIII). No microfilariae were found in the blood meal of black fly specimens taken from wild trapped moose (Table XIV).

TABLE XIII

PRESENCE OF ONCHOCERCA CERVIPEDIS MICROFILARIAE IN BLACK FLY BLOOD MEALS FROM PENNED MOOSE

Blood Engorged	No. Examined	No. with Microfilaria	% with Microfilaria
S. venustum	169	5	2.95
S. decorum	101	2	1.98
S. arcticum	31	0	0
S. vittatum	22	0	0
S. aureum	2	0	0
P. formosum	4	0	0

TABLE XIV

PRESENCE OF ONCHOCERCA CERVIPEDIS MICROFILARIAE IN BLACK FLY BLOOD MEALS FROM TRAPPED MOOSE

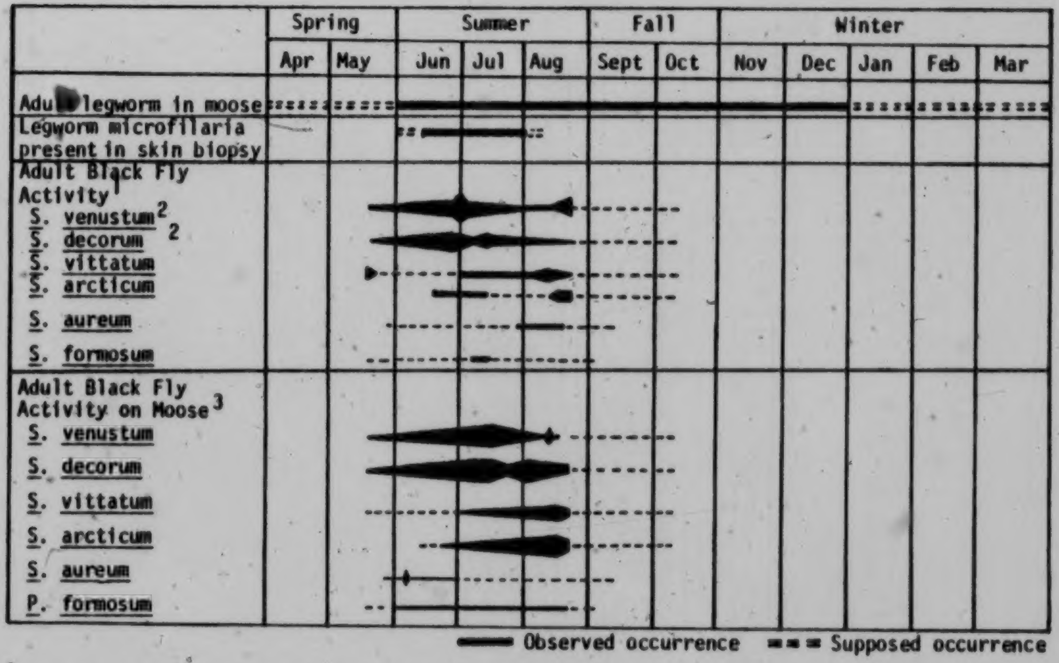
Blood Engorged	No. Examined	No. with Microfilaria
S. venustum	16	0
S. decorum	16	0
S. arcticum	2	0
S. vittatum	1	0

X. DISCUSSION AND CONCLUSION

To incriminate an arthropod with transmission of the causal agents of disease Barnett (1960) outlined four basic criteria. Firstly, effective contact with host under natural conditions must be demonstrated. In this study six adult black fly species fed on the blood of moose (Figure 101). These included S. decorum, S. venustum, S. arcticum, S. vittatum, S. aureum and P. formosum of which only the first four species were collected from wild trapped moose, and had blood engorged females collected from penned moose in both 1976 and 1977. Simulium decorum was the most abundant black fly species attracted to the penned moose followed by S. venustum and S. vittatum. Both S. decorum and S. venustum have a wide geographic distribution (Fredeen, 1973) as does O. cervipedis, and both are known blood feeders of large mammals (Fredeen, 1958; Davies, Wood and Peterson, 1962; Abdelnur, 1968).

Secondly, a temporal and spatial association of suspected arthropod species and occurrence of infection in host must be demonstrated. The microfilarial stage of O. cervipedis was present in the dermal tissue of the fore and hind limbs of moose sampled from mid June until early August (Figure 101). Both S. decorum and S. venustum were most abundant during mid June to late July, whereas S. vittatum was only abundant in early May and again in early July and S. arcticum was abundant in August in 1976 and June to September in 1977 (Figure 101). All four adult black fly species were collected from the hind limbs of wild trapped moose where the microfilariae are found.

Thirdly, repeated demonstration that the specific arthropod



[1] Includes only species that fed on the blood of moose, but excludes individuals taken from moose.

[2] Microfilariae of O. cervipedis found in blood meal.

[3] Includes only species that fed on the blood of moose.

Figure 101. Summary of Onchocerca cervipedis and Adult Black Fly Activity of those Species that Blood Fed on Moose in the Swan Hills.

harbours the infectious agent in the infective stage under natural conditions must be shown. No infective stage O. cervipedis was found; however, microfilariae were found in the blood meals of blood engorged S. decorum and S. venustum. While this does not satisfy this third criteria in incriminating a vector it does reveal two possible vectors. In this study relatively few blood engorged black flies (364) were examined for microfilariae, future investigations should include a more extensive examination of the species known to blood feed on moose to obtain more valid results. Further work must also be done to show O. cervipedis can develop to the infective stage in S. decorum and/or S. venustum. As well the fourth criteria, that of demonstrating transmission of infectious agent to definitive host under controlled conditions has yet to be done.

The filarioid nematode inhabiting the subcutaneous connective tissue of moose from the Swan Hills area of Alberta has been identified as O. cervipedis. Discrepancies in the distance of the nerve ring to the anterior extremity in the females, the longer small spicule in the males and the length of the microfilariae could be attributed to a different geographic strain of legworm or to the different host.

Adult legworms were present in 64.0% of the moose examined. Localization of adult legworm in the lower limbs of moose, particularly around the tibio-tarsal joints is in agreement with numerous authors including Rush (1933), Annereaux (1941), Herman (1945) for deer and Samuel et al. (1976) for moose. In general adult legworm showed a marked preference for the front limbs with the majority of worms (80.0%) inhabiting that area. This agrees with Samuel et al. (1976) and Brown (1961) who found the front limbs more heavily infected than the hind limbs of moose and black-tailed deer, although Cowan (1951), Anderson (1962) and Wienmann (1973) reported a preference for the hind limbs in black-tailed deer. The front limbs in moose 2.5-6.0 years of age were infected more commonly with legworm than the hind limbs.

The possibility of different strains of _O_. _cervipedis_ with distinct behavioural characteristics should be considered. _O_. _cervipedis_ is a recent parasite of North American moose, likely acquired after the immigration of moose from Eurasia (Anderson and Lankester, 1974) in the Illinoian age (100,000-175,000 years ago) (Pewe and Hopkins, 1967 in LeResche _et al._, 1974). The different host (moose) and the period of time moose have been in North America could have resulted in the evolution of strains of _O_. _cervipedis_ with distinct behavioural characteristics resulting in the differences of site location.

Older moose were more heavily infected with legworms than younger moose, no adult legworms were recovered from calves or yearlings. The increase in the number of adult legworms with age of moose was linear (correlation coefficient r=0.75). However, other factors such as the prevalence of legworm in the moose population, density of host and vector(s) could be important in determining abundance of legworm in moose. Beaudoin _et al_. (1970) suggested age composition and density of host population as well as the ecological factors of the external habitat may be important factors affecting the increased abundance of _O_. _cervipedis_ with age in white-tailed deer. Weinmann _et al_. (1973) found worm burden did not increase linearly with age of Columbian black-tailed deer. In moose calves the length and density of the natal hair could afford some protection from biting flies since the black flies generally blood feed on the sparsely haired area of the host. On cattle, adult S. ornatum (Meigen, 1818) bite predominantly around the umbilicus where hair is sparse and easily penetrated (Eichler, 1971).

By late July when the natal hair of moose calves has been shed, the peak legworm transmission period could be over. Weinmann et al. (1973) predicted this to be the situation in fawns of Columbian black-tailed deer. More important is that the moose calves and yearlings may be infected, but a long patency period and the lack of knowledge about immature stages in the moose may prevent locating the legworm. Seven of the blood engorged adult black flies (5 S. decorum, 2 S. venustum) taken from the penned yearling moose in 1977, contained microfilariae in the blood meal, indicating the moose was exposed to the infective stage larvae as a calf in 1976. Samuel et al. (1976) reported 11.0% of moose calves (4-9 months) and 73.0% older moose infected with legworm.

Adult legworms were found in an extended or coiled position. Coiled legworms were found either free or in nodules, with up to seven females in a nodule. The number of calcified legworms was not dependent on host age and may be related more to individual host resistance or to exposure of a high incidence rate for a given year.

Male legworms were rarely encountered in moose. The sex ratio of 2.2 males per 100 females (13:595) was in reasonable agreement with the 1.7:100 male to female ratio reported by Herman and Bischoff (1946) for deer. Weinmann et al. (1973) reported a 3.3:100 male to female sex ratio for legworm in Columbian black-tailed deer.

Weinmann (1973) has demonstrated seasonal periodicity in the production of microfilariae with peak abundance in the skin in spring and summer. These microfilariae concentrate in the ear of Columbian black-tailed deer and are abundant when the females of the incriminated vector, Prosimulium impostor, are active. In moose in this study, microfilariae were recovered from skin biopsies from 53.0% of the 17 moose sampled between mid June and July. No microfilariae were found in the skin of 21 moose sampled in September and October even though 53.0% (8 of 15) had adult legworm. This tends to support seasonal periodicity of microfilariae in skin reported by Weinmann (1973).

What happens to the microfilariae in autumn is not known. Weinmann (1973) suggested a halt in production of microfilariae which would explain their absence if they have a short life span (4-5 months). However, if the microfilariae survival time is longer, such as the 30 months reported for microfilariae of O. volvulus (Nelson, 1970) perhaps they inhabit other tissues of the host's body during part of the year.

That microfilariae were found only in the front and hind limbs in close association with the adult legworms could tend to support Hibler's (1965) view that microfilariae are found in association with the adultlegworms regardless of their location. However, the adult black fly blood feeding activity on both wild and penned moose was concentrated on the sparsely haired areas of the legs, particularly the hind limbs, where the microfilariae were more abundant, suggesting the microfilariae were present at the preferred black fly blood feeding sites on the host and is in agreement with Weinmann et al. (1973), but not with Hibler (1965).

The incrimination of the adult black fly P. impostor in vectoring O. cervipedis in Columbian black-tailed deer in California (Weinmann, 1973), directed the examination of adult black flies as possible vectors of O. cervipedis in moose of Alberta. Although various authors (Murie, 1934; Peterson, 1955; Flook, 1959) have noted that moose, like cattle and horses, are annoyed by biting flies, little is known about the species involved (Anderson and Lankester, 1974). This is particularly true of black flies where in Alberta no records exist. In Minnesota only S. venustum and S. pictipes have been reported from moose (Olsen and Festermacher, 1942; Nickholson and Mickel, 1950) and from the Northwest Territories, S. luggeri and S. malyschevi were swarming over an area just vacated by a moose (Flook, 1959).

In addition to the lack of information about blackflies affecting moose was a lack of information about blackfly species in the Swan Hills area and their adult activity patterns. In northern Alberta, Abdelnur (1968) and Fredeen (1969) have studied blackflies in the agricultural areas. It was therefore necessary to determine what adult blackfly species were present to derive a meaningful interpretation of what black flies affected moose and which species might be vectors of O. cervipedis in moose.

Twenty-one adult blackfly species were collected from the study site. Seventeen species have been confirmed by Dr. B.V. Peterson, Canada Agriculture; the remaining six species have been tentatively identified. Simulium euryadminiculum and S. jenningsi are new records for these species in Alberta.

Of the 21 blackfly species in the study area fourteen were attracted to moose, but only adults of six species took blood meals. These were: S. decorum, S. venustum, S. arcticum, S. vittatum, S. aureum and P. formosum (Table 13). The S. venustum complex was the most abundant species encountered and second most abundant attracted to the penned moose (Figures 45 and 62). Adults of this species were active throughout the 1976 field season and showed three peak activity periods between June 19 and August 20. This activity is in agreement with Fredeen (1958, 1973) who noted initial emergence 5 to 8 weeks following ice break-up of the streams. S. venustum adult can be a serious pest of humans, cattle and horses (Fredeen, 1958; Davies, Wood and Peterson, 1962; Abdelnur, 1968), ruffed grouse (Bennett and Fallis, 1958) and sparrows (Abdelnur, 1968). Adults of this species transmits the avian blood protozoon Leucocytozoon simondi (Fredeen, 1958). Simulium venustum was actively attracted to moose as apparent in the moose baited fly trap, being most active in June and July (Figures 45 and 62). Adults consistently blood fed on the wild trapped and the penned moose in 1976 and 1977 (Tables 13 and 14). In 1976, 5.6% and in 1977, 6.14% of the females taken in the moose baited fly trap were blood engorged. This percentage of blood feds was not considered unreasonable since Davies (1957) indicated 8.0-25.0% of the S. ornatum landing on cattle actually blood fed and Eichler (1971) noted that most S. ornatum landing on cows failed to feed on that host. On wild moose, blood feeding activity was concentrated on the inner and outer aspects of the legs, particularly the hind leg. Reduced activity was noted in the belly, brisket and anal regions. There was no marked tendency to blood feed on the ear or head region of moose as observed by Smith in Algonquin Park, Ontario (cited in Anderson and Lankester, 1974).

Adults of S. decorum were the second most abundant black flies (Figures 13 and 30) and the most abundant collected from moose (Figures 46 and 61). This multivoltine species is widely distributed in Canada

(Fredeen, 1973). In 1976 three peak abundance periods were recorded with the species being most abundant in June and July (Figures 13 and 30). Primarily a pest of humans and horses, it has also been reported to feed on the blood of birds (Davies, Wood and Peterson, 1962; Abdelnur, 1968). Adults were actively attracted to the moose baited fly trap with 0.46% and 0.85% blood engorged in 1976 and 1977, respectively. Blood engorging adults were also collected from the hind legs of immobilized wild moose where they concentrated their feeding activity.

Adults of S. arcticum were abundant throughout the summer with peaks in abundance in mid-July and August (Figures 15 and 33), suggestive of two generations. Sommerman et al. (1955) reported two generations per year. Restricted to western North America, this species is a facultative blood feeder of horses and cattle (Abdelnur, 1968), gathering on the sparsely haired portions of the animal to feed (Peterson, 1959). In localized areas of Alberta and Saskatchewan adults of this species have caused economic losses to the livestock industry (Fredeen, 1969). Besides horses and cattle, S. arcticum likely blood feeds on mule deer (O. hemionus hemionus) (Peterson, 1959). Although adults were actively attracted to and blood fed on moose (Figures 47 and 63, Tables 13 and 14), their restricted geographic distribution may reduce their potential as a vector of O. cervipedis.

Adult S. vittatum was first collected from the muskeg community on May 15, 1976 (Figure 17), but not from the forest community until July 3, 1976. The reason for this discrepancy is not apparent unless it relates to the timing of ice break-up at the breeding site as in a forest covered area, where ice break-up is later. Three peaks in abundance were recorded. The first major peak in mid-May relates to the fact that larval and pupal stages of S. vittatum overwinter so that adults emerge early in spring (Fredeen, 1958; Fredeen and Shemanchuk, 1960). The number of generations per year varies from 2-4 depending on geographic region (Sommerman et al., 1955; Fredeen and Shemanchuk, 1960). Although primarily a pest of humans, horses and cattle (Peterson, 1956; Fredeen, 1958; Davies, Peterson and Wood 1962; Abdelnur, 1968) in some regions adults of S. vittatum are not reported as pests of humans (Sommerman et al., 1955; Peterson, 1956). Such differences in haemophily are major problems in determining the relationships of black flies and their hosts. It has been shown that the preferred hosts of a black fly species can vary with geographic area and time of year (Peterson, 1956), and for that reason implication of black fly vectors can be difficult. For instance, in 1976 blood fed adults of S. vittatum were collected from wild trapped moose, but not from the penned moose. At that time the penned moose was a calf and may not have had all the correct stimuli to induce blood engorgement, or perhaps more likely the long dense natal hair, prevented the black flies from reaching the skin to obtain a blood meal. In 1977, when the moose calf's natal hair was gone, 6.7% of the adults taken from the moose baited fly trap were blood engorged (Table 13).

Similarly P. formosum was attracted to the penned moose in 1976, but no blood engorged individuals were collected; while in 1977, 53.4% of those from the moose baited fly trap were engorged (Table 13). Unlike S. vittatum this species was present in low numbers throughout the summer.

S. aureum has been reported as a multivoltine species by various authors (Stone et al., 1955; Davies, 1950; Peterson, 1959), however during 1976 and 1977 one peak each year was recorded (Figures 20, 36 and 65). In 1976 this occurred from August 7-20 (Figures 20 and 36) and in 1977 from June 5-11 (Figure 65). Abdelnur (1968) reported adult emergence on June 20 in the Flatbush and Irish Creek areas of Northern Alberta. Most authors have designated *S. aureum* as a bird blood feeder, (Peterson, 1959 c; Stone *et al*., 1955; Bennett and Fallis, 1958), although Abdelnur (1968) noted it blood fed on cattle and in this study blood engorged individuals were collected from the penned moose (Table 14). Because of the divergent feeding behavior of *S. aureum* in north central Alberta it should be investigated further to determine if it is a sibling species of those reported by the above mentioned authors.

Confined moose exhibited a response to high biting fly activity. The moose calf with its long, dense natal hair seemed less disturbed by the fly activity than older moose. Moose moved constantly about the penned area, ear twitching, muscle spasms and rubbing their hind legs together in a stamping motion in an apparent attempt to dislodge the flies. It is not unreasonable to assume that moose are as susceptible to the annoyance of black fly attacks as Fredeen (1969) noted for cattle. If wild ungulate farming of moose in Alberta is deemed feasible, care in the selection of farm location with respect to biting fly populations must be considered. As natural moose behavior patterns which afford some protection from adult biting fly activity may be modified under confinement, some artificial protection such as use of insect repellents applied by self applicators should be investigated. This study showed black flies blood fed primarily in the sparsely haired areas of the legs, brisket, belly and anus, with concentrated activity on the hind limbs around and below the tibio-tarsal joints. Therefore, use of dust bags and back scratchers containing insect repellents like those used for cattle should be investigated. These should be placed in areas used frequently by moose during the adult biting fly season, such as along game trails, at mineral licks or watering areas.

The objective of this study was to provide a more comprehensive understanding of the host-vector-parasite relationship of the legworm, *O. cervipedis*, in moose of the Swan Hills, Alberta. Six specific goals were established and have been reached, at least in part. The legworm of moose at the study site was identified as *O. cervipedis*. Sixty-four percent of the moose examined were infected with legworm of which 80.0% were located in the fore limbs and 20.0% in the hind limbs. There was a linear increase in the number of legworms with increasing age of the moose, but no host-sex preference could be determined because of a lack of hunter-killed and road-killed female moose. Microfilariae of *O. cervipedis* were present only in the skin of the fore and hind limbs of live-trapped moose during June and July suggesting there is a seasonal periodicity in the skin of moose. The seasonal activity of the adults of 21 black fly species was monitored at the study site, *S. venustum* and *S. decorum* were abundant during June and July. Adults of six black fly species fed on the blood of moose, but microfilariae of *O. cervipedis* were found only in the blood meals of *S. decorum* and *S. venustum* incriminating these species as possible vectors.

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APPENDICES

APPENDIX 1

1976 WEATHER RECORD AT STUDY SITE (54°46' N115°5')

Date	Time	Temp. °C	Barometric Pressure*	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
May 19	0830	7	--	80	0	0
	1100	11	--	70	0	0
	1300	11	--	65	0	2
	1500	--	--	62	0	2
	1900	13	--	59	0	2
	2100	10	--	64	0	3
20	0900	11	--	68	0	0
	1300	15	--	58	0	4
21	1000	12	--	80	0.51	5
	1600	14	--	64	0	4.5
	2300	13	--	66	0	0
22	1200	18	--	54	0	4
	2300	17	--	53	0	0
23	1100	22	--	48	0	2
24	0900	16	--	66	0.13	3
	2030	14	--	4	0.13	0.5
26	1000	15	--	48	2.03	3
	1600	20	--	42	0	0
27	0630	4	--	78	0	0
	0900	12	--	64	0	0
	2000	16	--	60	0	4- 8
	2200	10	--	78	0	5-10
28	0800	7	--	56	0	2- 4
	1600	12	--	47	0	2- 3
29	0600	2	--	79	0	0
	0900	10	--	68	0	2- 3
	2000	12	--	54	0.63	0

*Barometric pressure was not recorded in 1976.

APPENDIX 1 (Continued)

Date	Time	Temp. °C	Barometric Pressure*	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
June 14	0600	8	--	--	0	0
	0830	18	--	50	0	0
	2000	13	--	59	0	2-4
15	0800	11	--	71	0	2
16	0800	12	--	52	0	0.5-1
	1000	11	--	54	0	2-4
	1200	13.5	--	51	0	3-5
	1400	14	--	50	0	3-4
	1600	14	--	48	-	2-4
	1800	15	--	42	0	4-8
	2000	14	--	48	0	3-5
	2230	8	--	64	0	0
17	0800	18	--	51	0	1
19	0800	14	--	--	0	4-5
20	0830	8	--	72	1.0	4-6
21	0900	12	--	68	0.5	1
23	0800	7	--	84	0.89	0
	1000	8	--	82	0.13	0
	1400	11	--	74	0.05	1-5
	1800	9	--	78	0	0
	2000	8	--	88	0.05	0
24	0800	7	--	83	1.9	0-5
	1000	8	--	77	0.02	5-7
	1600	10	--	72	0.02	4-7
25	0800	11	--	76	0.25	2-3
	1530	10	--	72	0.56	1-5
	1800	13	--	66	0.25	3
	2000	11	--	73	0.31	0

APPENDIX 1 (Continued)

Date	Time	Temp. °C	Barometric Pressure*	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
June 26	0800	8	--	86	0.36	3
	1600	9	--	88	1.52	5
27	0700	8	--	86	0.51	0
	0900	14	--	78	0	3
	1700	15	--	66	0.38	2
	2000	12	--	74	0.12	--
28	0900	16	--	74	0.16	--
	1600	21	--	48	0	5
	1900	20	--	52	0	2-3
29	0900	17	--	60	0	1-3
	1700	22	--	53	0	3-5
30	1200	20	--	60	0	1-2
	1400	20	--	59	0	--
	1600	20	--	62	0	1
	1900	20	--	70	0.10	--
	2000	17	--	74	0	--
July 2	0800	20	--	70	2.29	--
2	1100	15	--	60	0.81	2-3
	1700	20	--	44	0	2-5
	2030	13	--	59	0	--
3	1000	16	--	46	0	1-5
4	1100	21	--	46	0	4-8
	1600	21	--	45	0	2-5
	1730	19	--	50	0	1-6
	2000	17	--	53	0	1-5
5	0900	16	--	56	0	4-9
	1600	21	--	49	0	--
6	0900	20	--	54	0	1-5

APPENDIX 1 (Continued)

Date	Time	Temp.^{o}C	Barometric Pressure*	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
July 6	0900	20	--	54	0	1-5
	2000	21	--	50	0	1-3
7	0900	12	--	80	0.12	0
	1200	22	--	56	0	1
	1600	27	--	48	0	3
	2000	20	--	70	0	0
8	0800	18	--	50	0.12	2
	1600	20	--	62	0.08	0.5
	1800	19	--	72	0.38	0
9	0800	18	--	60	2.28	3-5
	1600	18	--	61	0	0
	1800	16	--	70	0	4-5
	2000	14	--	--	0	3-4
10	0800	10	--	80	1.14	0
	1600	20	--	50	0.13	1
	1800	18	--	60	0	0.5
11	0800	16	--	70	0	0
	1700	22	--	70	0	4-5
	2000	12	--	72	0.25	1
12	0800	10	--	80	0.20	3
	1000	15	--	74	0	1-2
13	0830	17	--	70	0	1-4
	1530	17	--	67	0	4-7
	2000	13	--	76	0	2
14	0800	10	--	82	1.3	0
	1200	11	--	80	0.30	0.5
	1800	16	--	--	0.05	3-5
15	0830	17	--	71	0	2

APPENDIX 1 (Continued)

Date	Time	Temp. °C	Barometric Pressure*	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
July 16	0900	21	--	58	0	0.5
	2100	22	--	52	0	0
18	1000	17	--	43	0	0.5-4
	1700	18	--	46	0	2
19	0800	24	--	40	0	2
20	0800	17	--	60	0	1.5
	1600	20	--	62	0	2- 5
	2000	19	--	66	0	1- 3
21	0800	19	--	68	1.62	1
	1200	19	--	--	0	0
	1600	18	--	58	0	7-10
22	0800	10	--	40	0	3- 5
	1000	15	--	56	0	3- 5
	1600	20	--	44	0	5- 7
23	0800	10	--	78	0	0
	1600	21	--	50	0	3
	2000	20	--	50	0	0
24	0830	16	--	70	0	0
25	0800	14	--	50	0	5- 7
	1600	22	--	40	0	2
26	0800	10	--	80	0.05	0
	1000	11	--	80	0.05	1
27	0900	11	--	66	0	1- 2
	1600	14	--	68	0	5-10
	2000	10	--	84	0.10	5-10
28	0800	12	--	72	0.13	3- 5
	1200	12	--	76	0.08	1
	1600	10	--	79	0.13	3- 4

APPENDIX 1 (Continued)

Date	Time	Temp. °C	Barometric Pressure*	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
July 28	2000	10	--	80	0.05	1
29	0800	11	--	84	0.56	3
	1700	16	--	60	1.02	2-3
	2000	14	--	70	0	0
30	0900	13	--	78	0	1
	1700	15	--	75	1.02	1
	2000	14	--	76	0	0
31	0800	12	--	83	1.69	1-5
	1600	17	--	78	0.25	4-5
Aug 1	1000	14	--	80	0.25	1-2.5
	1700	18	--	70	0	1
2	0900	18	--	67	0	1-2
3	1300	18	--	74	0	0
4	0800	16	--	80	0.13	0
	1200	19	--	64	0	0
	1600	22	--	60	0	2
	2000	20	--	63	0	0
5	0800	14	--	69	0	0
6	0800	20	--	62	0	0
	1600	23	--	48	0	1
7	0800	14	--	80	0	0
	1600	22	--	64	0.2	0
	2000	18	--	65	0	0.5
8	0800	14	--	82	0.25	0
	1600	20	--	70	0.18	1
	2000	17	--	74	0	0
9	0800	14	--	83	0.46	0
	1600	18	--	74	1.02	0

APPENDIX 1 (Continued)

Date	Time	Temp.°C	Barometric Pressure*	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
Aug 9	2000	15	--	78	0.51	0
10	0800	14	--	80	0.38	4- 5
	1600	20	--	56	0	2
11	0800	20	--	60	0	0
	1200	21	--	58	0	0
	1600	24	--	48	0	0
	2000	20	--	69	0.05	0
12	0800	16	--	78	0	1- 3
	1000	17	--	75	0.20	1- 3
	1600	21	--	61	0	0.5
13	0800	12	--	81	0	0
	1500	22	--	60	0	2- 4.5
14	0800	14	--	83	0	1
	1300	22	--	62	0	1- 2
	2000	21	--	65	0	0
15	0900	16	--	80	0	1.5
	1600	23	--	58	0	1- 2
16	1000	18	--	72	0.63	2.5
	1600	20	--	65	0	2
17	0900	11	--	80	2.29	2- 7
	1200	13	--	77	0	3- 7
	1700	12	--	80	0.38	5-11
18	0800	12	--	75	0.1	4- 5
	1200	15	--	56	0	5- 8
	1600	19	--	51	0	3- 4
	2000	14	--	68	0	0
19	0800	14	--	70	0	0
	1600	18	--	56	3.04	0

APPENDIX 1 (Continued)

Date		Time	Temp. ^{o}C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
Aug	19	2000	10	--	80	0.81	0
	20	0800	13	--	78	0.13	1
		1600	15	--	56	0	5-8
		2000	12	--	63	0	0.5
	21	0800	15	--	60	0	1-2
		1700	18	--	48	0	1.5
	22	0800	12	--	76	0	0
		1600	20	--	50	0	1-2
	23	0800	10	--	82	0.38	0
		1600	19	--	70	0.05	0
	24	0800	10	--	85	0.51	0

APPENDIX 2

1977 WEATHER RECORD AT STUDY SITE ($54^o46'$ N$115^o5'$)

Date	Time	Temp. ^{o}C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
May 13	1030	13.5	747	51	0	0
	1600	19	744	40	0	0
	2000	17	--	--	0	0
14	0830	11	747	56	0	2.5
	1600	16	747	46	0	0.5
15	0845	9.5	749	70	0	0.5
	1700	12	749	54	0	0.5-7
16	0830	2	750	84	3-4 Snow	0
	1600	4	751	80	0	0
17	0830	4	751	82	0	0
18	0920	6	757	80	0	0
	1020	10	755	74	0	0
	1600	10	756	74	0	0
	1800	13	754	62	0	0.25
	2000	10	754	64	0	1.0
19	0830	10	754	66	0	0.5
	1730	16	749	48	0	1.5
	2030	15	749	52	0	1.5
20	0830	11	748	52	0	5.5
	1630	16	744	34	0	6.0
21	0800	14	744	52	0	1.5
	1000	16	745	46	0	2.0
	1600	22	739	42	0	0.5
	1800	18	743	50	0	3.0
22	0800	10	750	56	0	4.0
	1600	16	743	44	0	0.25
23	0830	15	746	68	0	0.5
	1600	20	740	52	0	2.0

APPENDIX 2 (Continued)

Date	Time	Temp. °C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
May 24	0830	12	744	84	0	0.5
	1000	12	742	82	0	0.5
	1600	21	738	52	0	1.5
	1800	12	745	78	0	0.5
	2000	11	745	82	0	0.5
25	0800	8	744	52	0.86	2.0
26	1200	18	--	--	0	0
27	0800	10	--	75	0.51	0
28	1600	10	--	--	0	2-4
31	0800	8	751	68	1.6	0
	1030	17	751	56	0	3-4
	1600	20	747	56	0	2-4
	1800	22	743	46	0	3-5
	2000	19	747	48	0	2.0
Jun 1	0800	13	746	58	0	0
	1830	22	740	56	0	1.0
2	0800	8	747	--	0	6.0
	1045	10	747	--	0	3.0
	1600	15	745	--	0.02	2-4
	1800	14	744	--	0	5-7
3	0830	9	746	68	0.02	1.5
	1700	18	743	39	0	0
4	0800	10	746	50	0	1-3
	1730	16	749	63	0	1-3
5	0830	14	749	50	0	0.5
	1000	17	749	52	0	0.5
	1200	20	749	50	0	0
	1600	24	746	40	0	0

APPENDIX 2 (Continued)

Date	Time	Temp. °C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
June 5	1800	23	746	41	0	0
	2000	22	745	41	0	0
6	0830	17	747	48	0	1.5
	1000	20	746	43	0	3.0
	1600	23	741	44	0	0-10
	1800	26	740	38	0	2- 4
	2000	26	739	43	0	1- 3
7	0800	15	741	48	0	0
	1600	29	734	44	0	1- 3
8	0800	11	744	82	1.27	0
	1000	17	738	82	0	0
	1600	20	736	54	0	4- 8
	1800	18	738	54	0	1- 3.5
	2030	16	742	60	0	0
9	0800	10	742	50	0	3- 7
	1600	14	742	65	0	2- 5
10	0800	4	750	62	0	1- 3
	1600	14	750	51	0	0.5
11	0300	6	750	70	0	0
	1000	10	750	57	0	0.5- 2
	1600	15	750	52	0	1- 3
	1800	15	750	54	0	0
	2000	15	750	57	0	0
12	0800	9	750	46	0	0
	1600	14	750	76	0.38	0
13	0800	10	752	77	0.46	0
	1600	16	749	76	0.41	0
14	0800	10	753	84	1.29	0

APPENDIX 2 (Continued)

Date	Time	Temp. °C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
June 14	1000	12	[illegible]	84	0.02	0
	1600	18	749	68	0.05	3-5
	1800	17	750	66	0.05	2-4
	2000	14	751	73	0.05	1-2.5
15	0830	10	754	82	0.05	0
	1630	20	749	50	0	2.0
16	0830	14	746	54	0	1
	1000	16	747	52	0	1
	1600	20	747	66	0.08	4
	1800	18	748	60	0	0 .5
17	0800	13	740	44	0	0
	1000	16	749	56	0	0
	1600	23	743	50	0	0
	1800	23	742	46	0	0
	2000	23	741	42	0	3
18	0800	16	749	62	0	1
	1600	22	745	52	0	3
19	0830	11	747	56	0	0
20	0800	14	739	63	0	0
	1000	20	740	62	0	0.5
	1600	27	733	50	0	3-6
	1800	26	736	52	0	0.5
	2000	18	743	75	0	2-5
21	0800	14	738	48	0.02	1-3
	1100	18	742	56	0	0.5-1.5
	1200	20	741	55	0	0.5-2.5
	1600	26	735	47	0	0
	1800	25	736	52	0	0

APPENDIX 2 (Continued)

Date	Time	Temp. ^{0}C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
June 21	2000	22	738	59	0	0
22	0800	11	743	63	0.56	3-6
	1800	19	743	45	0	3-6
23	0800	12	742	39	0	0
	1000	14	748	48	0	0
	1600	22	742	42	0	0
	1800	22	742	43	0	0
	2000	22	741	48	0	0
24	0800	16	742	62	0	0
	1600	24	739	45	0	0
25	0800	12	746	62	0.76	3-6
	1600	19	744	47	0	3-6
26	0800	13	745	52	0	2.5
	1000	14	746	52	0	2-5
	1600	21	742	46	0	1.0
	1800	18	745	54	0	1-3
	2000	17	745	54	0	0.5
27	0800	11	749	70	0	1.5
	1600	22	745	49	0	3-5
28	0800	11	751	80	0.02	1.0
	1600	19	744	60	0.13	1-3
29	0800	9	751	84	0.36	3-5
	1600	16	751	78	0.56	3
	2000	16	750	78	0	2-5
30	0800	10	749	78	0.81	4-5
	1000	12	750	68	0	2-0
	1600	17	750	72	0.08	0
	1800	14	749	78	0.38	0

APPENDIX 2 (Continued)

Date	Time	Temp.^{o}C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
June 30	2000	16	748	76	0.48	0
July 1	0900	8	750	84	0.56	0
	1600	20	738	58	0	0
2	0900	9	745	82	0.10	6-8
	1600	18	741	52	0	4-8
	1800	17	741	54	0	3-5
	2000	15	745	58	0	5-8
3	0800	8	746	80	0.03	3-5
	1700	16	746	70	0	0.5
4	0800	10	747	74	0.02	0
	1000	13	747	70	0	0
	1600	15	748	73	0.33	0
	2000	16	747	74	0.51	0
5	0800	8	750	80	0.08	2-3
	1000	9	751	82	0.61	0
	1600	14	750	78	1.29	1.0
6	0800	9	751	86	1.63	2.0
	1600	14	751	82	0.84	2-4
	1800	13	754	80	0.86	4.0
	2000	12	755	80	0.89	1-3
7	0800	10	757	78	0.02	0.5
	1000	14	755	69	0	0.5-1.5
	2000	20	752	60	0	0
8	0800	10	746	55	0	1-2
	1600	22	746	55	0	3-6
9	0800	9	747	72	0	0
	1600	13	748	74	0.76	0
10	0800	12	750	80	0.76	0

APPENDIX 2 (Continued)

Date	Time	Temp. °C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
July 10	1000	14	748	72	0	1-3
	1600	21	746	66	0.02	0
	1800	20	746	65	0.02	0
	2000	19	747	70	0.02	0
11	0800	13	740	56	0.05	0
12	1200	10	751	82	1.68	0.5
13	0800	8	744	58	0	0
	1200	18	748	59	0	2-5
	1600	22	744	52	0	0
	1800	14	751	76	0.38	1.0
	2000	15	750	78	0	3-4
14	0800	8	754	77	0	0
	1000	10	754	73	0	0
	1600	18	750	64	0	0
	1800	18	750	65	0	0
	2000	16	751	70	0	0
15	0800	8	750	80	0.79	3.0
	1600	15	747	67	0.33	0
16	0830	10	750	80	0.38	0
	1000	14	750	73	0	0
	1600	20	742	60	0	2.0
	1800	20	744	66	0	2.0
	2000	17	745	72	0	0
17	0800	10	746	77	0.51	0.5
	1600	18	742	74	0	1-2.5
18	0800	9	746	62	0.02	2.0
	1000	10	746	66	0	0
	1600	17	744	50	0	0.5-1.5

APPENDIX 2 (Continued)

Date	Time	Temp. °C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
July 18	2000	15	746	60	0	5-6
19	0800	8	748	70	0	1-2
	1500	16	749	68	0	1-3
	1700	16	750	67	0	2-4
	1800	18	749	64	0	1-3
	2000	16	750	69	0	2-4
21	0800	15	746	65	0	0
	1700	22	743	62	0	0
22	0800	14	746	47	0	0.5-2
	1000	17	750	56	0	1-4
	2100	18	750	62	0	0
23	0800	10	747	70	1.52	0
	1700	20	750	50	0	0.5-1.5
	1800	20	750	52	0	4-6
	2000	19	752	55	0	1.5-4
24	0800	10	750	56	0	0
	1600	24	749	54	0	0.5-1.5
25	0800	12	753	73	0	0
	1000	14	752	66	0	1
	1600	26	745	54	0	2-3
	1800	26	745	56	0	1-2
	2000	24	745	62	0	0
26	0800	19	743	58	0	0-1
	1600	27	741	48	0	3-5
27	0800	18	744	58	0	0.5
	1600	28	739	54	0	0
28	0800	13	754	85	0.71	0
	1000	15	753	85	0	0-0.5

APPENDIX 2 (Continued)

Date	Time	Temp.°C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
July 28	600	17	751	82	0.08	0
	1800	16	751	82	0	0.5
	2000	16	751	82	0	0.5
29	0900	10	751	86	0	0.5-1.5
	1600	15	751	84	0.02	0
30	0900	12	751	82	0.38	3
	1600	21	747	53	-	7-9
31	0900	13	751	83	0.1	0.5-3
	1000	16	750	76	0	1-4
	1600	23	745	48	0	0.5-2
	2000	20	746	57	0	0.5
Aug 1	0900	15	750	65	0	2
	1600	21	748	56	0	5-6
2	0800	16	749	59	0	0
	1600	23	745	50	0	0.5-4
	1800	22	746	55	0	3-4
	2000	18	750	68	0	1.0
3	0800	13	754	80	0	0
	1000	13	753	78	0	2-5
	1600	16	753	78	0.13	1-2
	1800	18	751	68	0.13	2-5
	2000	14	754	75	0.13	2
4	0800	8	754	73	0.13	0
	1600	18	752	54	0	2-4
5	0800	14	746	60	0	0
	1600	20	747	65	0	3-5
6	1600	19	749	60	0.08	1.0
	1800	17	749	64	0	0

APPENDIX 2 (Continued)

Date	Time	Temp. °C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
Aug 6	2000	16	750	68	0	0
7	0800	10	750	76	0	0
	1600	14	750	80	0.18	3-6
8	0800	10	752	80	0	0
9	0800	6	756	76	1.27	1.0
	1000	8	758	75	0	1.0
	1600	16	755	52	0	3-6
	1800	17	755	52	0	3-5
	2000	15	755	57	0	0.5-1.0
10	0800	5	754	66	0	0
	1600	22	747	46	0	0
11	0800	13	753	80	0	0.5
12	0800	9	754	73	0.05	0.5
	1000	13	754	68	0	0.5
	1600	18	751	50	0	2.0
	1800	18	750	51	0	2.5
	2000	15	752	62	0	0.5
13	0800	4	755	79	0	0
	1600	18	752	54	0	2.0
14	0800	9	753	67	0	0
	1600	19	750	60	0.02	0
	1800	19	750	60	0	0.5
	2000	17	751	57	0	0
15	0800	9	756	81	0	0
	1000	12	754	76	0	0
	1600	20	749	54	0	2-4
	1800	14	754	75	0	1.0
	2000	16	752	75	0	0

APPENDIX 2 (Continued)

Date	Time	Temp. °C	Barometric Pressure	Relative Humidity	Precipitation (ml.)	Wind Speed m/s
Aug 16	0800	4	757	74	0.02	0
	1600	20	751	64	0	0.5-1
17	0800	12	750	72	0	0
	1600	24	745	57	0	0.5-1
18	0800	12	751	78	1.24	0
	1000	16	751	78	0	0
	1200	18	749	68	0	0
	1500	23	747	60	0	2-4
	1600	22	748	64	0	0-1
	1800	22	748	66	0	0.5
	2000	20	754	66	0	0
19	0800	11	756	80	0	0
	1600	22	750	69	0	0-1
20	0800	14	753	80	0	1.0
	1600	20	750	66	0	2-3
21	0800	10	755	84	0.02	0-1
	1000	-	758	84	0.08	0.5
	1600	15	755	62	0.18	0-2
	1800	14	754	62	0.18	1
	2000	13	756	64	0.18	0-1
22	0800	2	754	74	0.18	0
23	1600	11	754	83	0.15	0
24	0800	9	744	85	0.25	0
	1000	11	744	84	0.02	0
	1600	15	743	82	0.43	0
	1800	12	743	81	0.48	2.5
	2000	11	744	82	0.51	4-6

APPENDIX 3

FEMALE *ONCHOCERCA CERVIPEDIS* MEASUREMENTS

Character	Female Number									
	1	2	3	4	5	6	7	8	9	10
Total length (mm.)	201	191	167	196	202	194	188	164	193	171
Max. body width (μm.)	435	407	402	440	385	457	385	336	429	314
Nerve ring to anterior (μm.)	609	630	567	609	567	609	588	525	567	525
Esophagus to anterior (μm.)	1764	1932	1869	2016	1764	1134	1848	1260	1680	1260
Vulva to anterior (μm.)	1764	1869	1890	2121	1680	1092	1869	1260	1764	1449
Cloaca to posterior (μm.)	525	375	714	462	462	546	714	756	336	483

APPENDIX 4

MALE *ONCHOCERCA CERVIPEDIS* MEASUREMENTS

Character	Male Number 1	2	3	4	5	6	7
Total length (mm.)	59.9	53.0	52.0	56.0	59.0	56.0	63.0
Max. anterior width (µm.)	241	214	217	221	217	228	231
Max. mid body width (µm.)	-	235	231	224	231	242	231
Nerve ring to anterior (µm.)	287	308	301	329	294	308	294
Esophagus to anterior (µm.)	1554	1554	1932	1596	945	1155	1113
Long spicule length (µm.)	231	217	221	238	217	238	224
Short spicule length (µm.)	133	147	137	126	133	137	144
Anus to posterior (µm.)	206	203	168	168	182	168	172

APPENDIX 5

MEASUREMENTS OF MICROFILARIAL *ONCHOCERCA CERVIPEDIS*

Microfilaria No.	Total Length (μm.)	Max. Width (μm.)
1	291	7.0
2	238	5.8
3	235	7.0
4	242	7.0
5	315	5.8
6	281	7.0
7	273	5.8
8	294	7.0
9	287	7.0
10	107	7.0
11	238	5.8
12	322	7.0
13	231	7.3
14	270	5.8
15	224	7.0
16	294	7.0

APPENDIX 6

LETTER TO HUNTERS REQUESTING MOOSE

ATTENTION BIG GAME HUNTERS

Your assistance and co-operation is requested in gathering information on a parasite found in moose and mule deer. The parasite, called the legworm, is harmless in that it cannot infect man. It is only found in moose and deer. It has absolutely no effect on the edibility of your game animal.

The parasite lives under the skin (not in the meat) usually in the lower legs. Therefore, we require those portions of the legs below the hock. We'll need all 4 lower legs. The head and hide are also requested should you not want these parts (and should your kill be near your vehicle!)

We would prefer the materials as soon as possible after death of the host. Frozen specimens are fine and can be utilized.

Animals taken from Big Game Zones 1, 3 and 5 are of particular importance, but animals from elsewhere are welcome.

Should you want to donate portions of your game animal for this purpose, please contact David Pledger at 488-3398 or 432-4737.

Sincerely,

David Pledger,
Graduate Student,
Dept. of Entomology,
University of Alberta

Dr. Doug Craig,
Associate Professor,
Dept. of Entomology

Dr. W.M. Samuel,
Associate Professor,
Dept. of Zoology

APPENDIX 7

DISTRIBUTION OF ADULT O. CERVIPEDIS IN MOOSE, 1975

Specimen No.	Sex	Infected	Fore Limb Right	Fore Limb Left	Hind Limb Right	Hind Limb Left	Total Number of Adults
1	M	+	22	22	8	1	53
5	M	+	0	2	1	0	3
7	M	+	1	1	2	1	5
11	M	-	0	0	0	0	0
13	M	+	3	1	0	0	4
14	M	+	1	0	0	0	1
15	M	+	3	2	0	0	5
16	M	-	0	0	0	0	0
19	M	-	0	0	0	0	0
20	M	+	1	0	0	0	1
22	M	-	0	0	0	0	0
25	M	+	5	2	0	0	7
32	M	-	0	0	0	0	0
33	M	-	0	0	0	0	0
36	M	+	3	0	0	0	3
37	M	+	5	17	-	-	22
38	M	+	3	11	0	10	24
39	M	+	10	3	1	4	18
40	M	+	13	13	2	4	32
43	M	+	0	2	0	0	2
44	M	+	9	7	0	0	16
47	M	-	0	0	0	0	0
51	M	-	0	0	0	0	0
56	M	+	2	0	0	1	3
57	M	+	4	-	-	-	4
62	M	-	0	0	0	0	0
65	M	+	4	1	4	2	11
66	M	-	-	0	-	0	0
67	M	+	24	10	4	6	44
68	M	+	-	-	1	1	2
69	M	-	0	0	0	0	0

APPENDIX 7 (Continued)

Specimen No.	Sex	Infected	Fore Limb Right	Fore Limb Left	Hind Limb Right	Hind Limb Left	Total Number of Adults
81	M	-	0	0	0	0	0
85	F	-	0	0	0	0	0
87	F	+	2	2	0	0	4
104	M	+	13	5	4	4	26
106	M	+	26	11	4	1	42
107	M	-	0	0	0	0	0
114	M	-	0	0	0	0	0
115	M	+	8	-	-	0	8
116	M	+	6	17	0	0	23
118	M	+	37	29	11	11	88
119	M	+	6	5	1	2	14
120	F	+	38	37	12	7	94
121	F	+	11	15	6	2	34
122	F	-	0	0	0	0	0

Total number sampled	45
Total number males	40
Total number females	5

Number moose infected	29 (64.4%)
Number males infected	26 (65.0%)
Number females infected	3 (60.0%)

Prevalence $\frac{29}{45} \times 100\% = 64.4\%$

Total number adults	593
Total number in fore limb	475 (80.10%)
Total number in hind limb	118 (19.9%)

APPENDIX 8

ADULT *ONCHOCERCA CERVIPEDIS* DISTRIBUTION IN LIMBS OF MOOSE - 1975

Moose No.	Area of Limb					Total No. Adults
	Tibio-tarsal Joint	Tarsus		Phalanges		
		Tendon	Bone	Tendon	Bone	
1	18	13	12	4	6	53
5	0	0	3	0	0	3
7	3	1	1	0	0	5
13	3	1	0	0	0	4
14	1	0	0	0	0	1
15	0	2	0	3	0	5
20	0	0	0	1	0	1
25	4	3	0	0	0	7
36	3	0	0	0	0	3
37	5	9	8	0	0	22
38	9	11	3	1	0	24
39	10	4	4	0	0	18
40	18	7	2	0	5	32
43	0	1	1	0	0	2
44	0	10	6	0	0	16
56	0	1	1	1	0	3
57	3	1	0	0	0	4
65	1	6	4	0	0	11
67	16	15	11	1	1	44
68	0	0	2	0	0	2
87	2	1	1	0	0	4
104	13	6	7	0	0	26
106	17	7	18	0	0	42
115	4	3	1	0	0	8
116	9	5	7	0	2	23
118	22	21	40	3	2	88
119	0	2	12	0	0	14
120	43	11	35	1	4	94
121	19	7	7	0	1	34
Total N=29	223	148	186	15	21	593
% of Total	37.6	25.0	31.4	2.5	3.5	100

APPENDIX 9

AGE AND DATE OF KILL OF HUNTER-KILLED MALE MOOSE EXAMINED FOR *ONCHOCERCA CERVIPEDIS* MICROFILARIAE FROM SWAN HILLS IN 1975[1]

Date Killed	Age (years)
12-IX-75	2.5
20-IX-75	13.5
20-IX-75	14.5
25-IX-75	--*
26-IX-75	3.5
26-IX-75	6.5
26-IX-75	4.5
27-IX-75	--
27-IX-75	5.5
28-IX-75	1.5
28-IX-75	6.5
1- X-75	--
4- X-75	14.5
4- X-75	--
4- X-75	1.5
5- X-75	8.5
5- X-75	5.5
5- X-75	--
10- X-75	5.5
11- X-75	--
12- X-75	--

*No age available.

[1] Examined for microfilariae but negative.

XIII. VITA

NAME: David James Pledger

PLACE OF BIRTH: Calgary, Alberta

YEAR OF BIRTH: 1945

POST-SECONDARY EDUCATION AND DEGREES:

Northern Alberta Institute of Technology
Edmonton, Alberta
1965-1967 Forest Technology

University of Alberta
Edmonton, Alberta
1969-1973 B.Sc. (Hons.)

RELATED WORK EXPERIENCE:

Forest Technician
Environment Canada
1967-1970

Mosquito Control Personnel, Summer
City of Edmonton
1971-1972

Biologist
Alberta Department of the Environment
1973-